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A textbook of medical jurisprudence, toxicology and public health 1902

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tration of a noxious drug with a guilty intent, but that it must have been administered in sufficient quantity as to be noxious. As in this case the quantity administered was too small to effect grievous bodily harm, the man was acquitted. The other ruling was given by Lord Coleridge in R. *v.* Cramp.[1] The prisoner was charged with having administered half an ounce of Oil of Juniper, with intent to procure abortion. He was convicted, but appealed on the legal ground that the substance used must be noxious in itself, and not only when given in excess. Lord Coleridge ruled that "if a person administers, with intent to produce miscarriage, something which as administered is 'noxious,' he administers a 'noxious thing.'" It may, consequently, be taken that the law is so comprehensive that the most skilful poisoner shall not escape on technical pleas. For the law respecting the application of corrosives to the surface of the body, we refer the reader to p. 166, *et seq.*

LAWS REGULATING THE SALE OF POISONS.

The Acts of Parliament by which the sale of poisons in England and Scotland is regulated, are as follows: 31 & 32 Vict. c. 121 (1868), and the Amending Acts, 32 & 33 Vict. c. 117 (1869), 38 & 39 Vict. c. 63 (1875); and in Ireland, 33 & 34 Vict. c. 26 (1870), and the Amending Act, 38 & 39 Vict. c. 63 (1875). According to law, a medical practitioner who has passed an examination in pharmacy in order to obtain his degree or diploma, and who, after receiving such degree or diploma, is registered as a practitioner, is entitled equally with a duly qualified chemist under the Pharmacy Acts to keep an open surgery for retailing, dispensing, or compounding poisons, provided that in such sale he conforms to the requirements of the Sale of Poisons Acts. He is himself entitled to sell poisons, or he may depute the sale to a qualified assistant in his absence, but he is not entitled to depute the sale to an unqualified assistant. Where it is proved that his unqualified assistant so offends by selling poisons or preparations which contain poisons, he is liable, according to a recent notice of the General Medical Council, to be found guilty of conduct "infamous in a professional respect." All medicines containing poisons which he dispenses must be labelled with his name and address, and the contained poison, together with the name of the person to whom it is dispensed, shall be entered in a book to be kept by him for the purpose. It should be definitely and clearly understood that the law does not differentiate between the sale of a poison as a constituent of a medicinal mixture and the sale of a poison by itself. Poisons, according to law, are divided into classes or parts. The first Part includes such substances as Arsenic and preparations, Tartar Emetic, Mercuric chloride, Aconite, Atropine, and their preparations, Cantharides, as such, Ergot and preparations, Hydrocyanic Acid, Cyanides of metals, and preparations, Strychnia and preparations, all poisonous vegetable alkaloids and their salts, and all "vermin-killers" which contain any of the poisons named in this section. The second Part comprehends Oxalic acid, Belladonna, Chloroform, Oil of Bitter Almonds, Opium, Morphia, and their preparations, preparations of Mercuric chloride, Mercuric oxide, and Mercuric-ammonio-chloride, preparations of Cantharides, Chloral Hydrate and preparations, and all poisonous "vermin-killers," the poisons in which are not included in the former section. Should any poison, belonging to one or other of the foregoing sections, be sold, the seller must label the package with a label bearing the name of the poison or article, the name and address of the seller, and the word "poison." No poison included in Part I. may be sold to any one unknown to the seller, unless he be introduced by some one known to the seller, and until, before delivery, the seller enters in a book kept for the purpose, the date of sale, name and address of buyer, the name and amount of the poison sold, the purpose for which the poison is to be used, and until the entry is signed by the buyer and by the introducer. In the case of the sale of arsenic, even further restrictions are

[1] *Times*, March 1, 1880.

imposed. If the purchaser be not known to the seller he must be introduced to the latter by a person who knows both of them, and who acts as witness of the sale. Besides the above details to be entered as the record of the sale, both the seller and the purchaser must sign the record. By The Sale of Arsenic Act—14 & 15 Vict. c. 13 (1851)—no arsenic can be legally sold to a person under the age of 21 ; nor may it be sold in quantities of less than 10 lbs.; unless it be mixed with soot or indigo in the proportion of one ounce of the former, or half an ounce of the latter, to each pound of arsenic. When quantities of 10 lbs. or upward are sold for any purpose for which it would be unfitted by the above admixture, it may be sold without it. By the Act 26 & 27 Vict. c. 113, it is the law that " every person who shall knowingly and wilfully sow, cast, set, lay, put, or place, or cause to be sown, cast, set, laid, put, or placed into, in, or upon any ground or other exposed place or situation, any grain, seed, or meal which has been steeped or dipped in poison, or with which poison or any ingredient or preparation has been so mixed as thereby to render such grain, seed, or meal poisonous and calculated to destroy life, shall, upon a summary conviction, be liable to a penalty of any sum not exceeding £10." In a case tried in 1891, before the magistrates at Chelmsford, where a woman had put down some pieces of bread poisoned with phosphorous paste, and which was fully proved in evidence, she was acquitted, because the Act says nothing about bread. In view of the foregoing necessary stringent regulations, it is somewhat surprising to find that patent medicines which contain some of the above poisons may be sold without any such restrictions whatever. This anomalous state of matters has not yet been remedied, although the attention of the law officers of the Crown has been called to the fact by coroners and by the medical profession. It is, however, as illegal for an unqualified person to sell patent medicines which contain poisons as any other medicine containing a poison, or a poison itself.

In what Ways do Poisons Act ?—It may be said that their action is either (1) Local, or (2), Remote. They either kill or menace life by destroying the tissues with which they come in contact, or they produce these effects by being absorbed into the circulation, and thus act on organs, more or less remote from the point of their absorption, as the brain and spinal cord, or heart. Although the mineral acids, the caustic alkalies, and the corrosive salts destroy more or less extensively the parts they touch, death is not due in all these classes to the same prime cause ; in the first, and, it may be, in the second, death is probably due to shock which the nervous system sustains, but in the third, while undoubtedly the local corrosive action is a factor in the production of the fatal result, the major factor is the absorption of the poison into the circulation. The irritant poisons, again, as arsenic, phosphorus, or cantharides, produce not only violent local irritation and inflammatory mischief, which of themselves may cause death by shock, but they do more mischief when they are absorbed into the body. With respect to the remote action of poisons, it is well known that toxic agents do not produce their poisonous results until they have been absorbed into the system, but that, when absorbed, certain of them act by election or preference upon certain organs more than upon others ; and it is by the undue interference with the normal function of such organs that death is produced, or life is menaced. Thus, opium, morphia, alcohol, and others affect chiefly the brain ; digitalis, baryta, strontia, oxalic acid (in certain doses), the heart ; prussic acid, tobacco, etc., the lungs ; and strychnia, the spinal cord. But certain others do not act upon any special organ, but upon the blood-stream itself ; such as Arseniuretted Hydrogen, Chlorate of Potash, Pyrogallic Acid, Carbon Monoxide, and others. Those poisons which do act remotely, are said

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to act physiologically in two ways, viz. : (1) By being absorbed into the blood and being carried to the organs which they more immediately affect; and (2). By their local effect being transmitted from the local nerves of the parts first attacked to the nerve-centres, and from thence reflected to the organs which the particular poison affects. If we take the case of a poisoned arrow stuck in the body, or the sting of a venomous snake, or the application of poisonous matter to an abraded absorbent surface, it is obvious that the poison must be absorbed into the general circulation before it can possibly produce its general poisonous effects, for, if the absorption be prevented by any measures promptly adopted, the poisonous results will be averted. Majendie's experiments conclusively show this. He connected the cut ends of vessels of the limbs of an animal with the body by interpolating pieces of glass tubing; and even then the poison acted. Dr. Blake[1] has demonstrated that if hydrocyanic acid be introduced into the stomach of an animal by a fistulous opening, after ligature of the portal vessels, no poisonous results will ensue; but that, immediately after removal of the ligatures, the poison begins to act. The second suggested method was the only way by which Christison believed the quick fatal results of the above acid could be accounted for. Blake's experiments, however, demonstrate clearly that even with respect to that poison, absorption was necessary, and was the means by which it acted. Moreover, Emmert has shown that where poison is inserted into limbs connected only to the body by the nerves, no poisonous effect is produced. We may, therefore, conclude that all poisons which act remotely, do so only by virtue of absorption, and that, although there is a sense in which corrosives by their action kill by shock to the nerve centres, it is better for our purposes to consider the burden of their action as primarily local, and, secondarily, central.

How may the Action of Poisons be Counteracted?—The effects of poisons may be counteracted by antidotes, which may be divided into three classes, because of their methods of counteraction, viz.: physical or mechanical, chemical, and physiological.

Mechanical or physical antidotes are but few in number. Some of them have, indeed, a chemical action to a limited extent. For example, white of egg or flour and water may be said to be mechanical antidotes in poisoning by corrosive sublimate, but at the same time, by the formation of albuminate of mercury which is practically insoluble in the stomach for the time being, they act partially as chemical antidotes. Probably, in the same way, animal charcoal may be reckoned as a mechanical antidote in alkaloidal poisoning, as by strychnia, but it is difficult to estimate how far the antidotal effect is not chemical because of the occluded oxygen. Mechanical antidotes may be said to exercise a beneficial effect in other cases only as they serve to dilute the poison and thus stay its effects; draughts of water or of demulcent fluids certainly act in this manner both in corrosive and irritant poisoning.

Chemical Antidotes.—These neutralise poisons by forming new compounds which either are insoluble, or less active; thus alkalies in acid, and dilute acids in alkali poisoning may be taken as the simplest

[1] *Edin. Med. and Surg. Journal*, vol. lvi. p. 56.

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[1] *Edin. Med. and Surg. Journal,* vol. liii. p. 55.

type; sulphate of magnesia in poisoning by carbolic acid of the second type, and sulphates of the alkalies in poisoning by lead or barium, of the first type. Freshly prepared sesquioxide of iron, made by treating tincture of perchloride of iron with excess of ammonia, filtering the precipitate, and after admixture with water, administering it to the patient, is also a chemical antidote in respect that it forms the comparatively insoluble arseniate of iron; and in a like manner, is tannin or its preparations in poisoning by tartar emetic.

Physiological Antidotes.—The mode of action of these must be differentiated. Chloroform may be said to exercise an antagonistic effect in strychnia poisoning, but all it really does is to overcome the tetanic contraction of the chest muscles which tends to kill the patient by asphyxiating him, and to give time and opportunity for the elimination of the poison from the stomach by surgical measures and from the body by the excretory channels. Atropine is held by many to be a physiological antidote to opium and morphia, and some maintain that the action conversely is equally well marked. To some degree, the theine of tea and caffeine in coffee may be held to be antidotal in action to the same poisons. Physiological antidotes are not always, however, reliable in their action.

Circumstances which may modify the Action of Poisons—

1. *Quantity.*—The larger the quantity and the severer the symptoms, the more rapid the fatal result, is the first conclusion at which we would naturally arrive. But there may be salvation in respect of some poisons, from the very excess in quantity inducing rapid and complete emesis. It is this question of quantity which separates the medicinal action of a poisonous drug, from its distinctively toxic action, and, as has been pointed out, which has prompted the law to differentiate between a poison and a noxious thing. It is also true of certain poisons that as is the quantity taken so is the action variable—for example, oxalic acid, in graduated quantities from larger to smaller, may kill from (*a*) shock; (*b*) action on the heart; (*c*) action on the spinal nervous system; (*d*) or action on the brain.

2. *Condition of Administration.*—A poison acts most rapidly when exhibited in a gaseous or vaporous form, next when injected subcutaneously, next when ingested in a state of solution, and least quickly, when in an insoluble form, and, therefore, difficult of solution in the stomach, or other part of the body; for example, a piece of opium in the rectum will take longer to act than if it had been swallowed. It is important to remember, however, that the question of solubility must be considered more with relation to the part to which it is applied than to the vehicle in which it is administered.

3. *Chemical Combination.*—It is well known that certain substances when in certain combinations are very poisonous, but that in others, are comparatively innocuous; and further, that while the component parts of a compound are poisonous singly, the compound itself is comparatively inert; thus sulphuric acid and baryta, while separate, are poisonous, but in combination form a salt, which, because of its insolubility, does but little harm except for its mechanical presence in the stomach.

4. *Mechanical Combination.*—When a powdery poisonous substance is administered with fluids of much lighter specific gravity the sub-

stance is liable to sediment in the vessel, and thus the quantity actually swallowed is less than where the vehicle of administration has been a fluid of specific gravity more nearly approaching that of the powder. It is by adopting this latter principle that the poisoner who uses arsenic administers it in a fluid which by its colour will mask the presence of the poison, and one which is heavy and viscid, such as porter, or cocoa, or coffee. Stewart has shown[1] that 100 grains of arsenious acid, mixed in a tea-cup with two teaspoonfuls of Epps' cocoa, boiling water and milk, could not be detected either by appearance, taste, or smell, but that on standing, the milk curdled, and the arsenic sedimented; and that with arrowroot and gruel the same results were observed. When a poison is given in an assimilable form with food, its action will appear more quickly than if it be administered shortly after a good meal. In a recent case, it was shown that where a man swallowed by mistake a tablespoonful of equal parts of aconite, belladonna, and chloroform liniments, the symptoms did not come on acutely until about three-quarters of an hour after, during which time he walked some distance, travelled by train, and walked at the end of his railway journey fully half a mile.

5. *The Part of the Body to which the Poison is applied.*—A poison acts most rapidly (1) when exhibited in a gaseous or vaporous form to the lungs; (2) when applied as a solution to serous surfaces; (3) when placed in contact with mucous surfaces; and (4) when applied to the unbroken skin. As examples of these may be taken chloroform, ammonia vapour, or carbon monoxide, the virulency of snake-venom when introduced into the circulation by the bite in the skin, and its innocuousness when swallowed, provided the mucous tract of mouth, gullet, and stomach is intact, and the inunction of mercury as oleate, by the skin.

6. *Habit.*—It is a matter of everyday observation that continuous indulgence in alcohol and tobacco, for example, confers a comparative immunity from danger from poisonous doses. In like manner, the opium habit may be contracted to such an extent that immense doses may be taken with impunity, as, for example, in the well-known case of De Quincey. Further, from continued use, strychnia and arsenic are borne in doses, which would be liable to act poisonously if taken to begin with. This is well established in the case of persons in Styria. Dr. Knapp of Obergeiring[2] saw a woodcutter of that neighbourhood swallow, after crushing in his teeth, a piece of arsenious acid weighing 0·33 gramme, without any ill effects, notwithstanding that examination of his urine by Marsh's process gave evidence of the presence of arsenic; and Stewart[3] narrates the fact of his own knowledge that a student in the College of Science, Dublin, used to eat little pieces of the same substance of about 3 or 4 grains, without apparent harm.

7. *Condition of Bodily Health.*—A small dose relatively will kill a weakly person, from which a stronger person would likely recover. In certain diseases, some drugs can be exhibited with impunity in doses which, in other circumstances, would be likely to prove harmful; as,

[1] "Trials for Murder by Poisoning," p. 395.
[2] Binz, *Pharmacology*, vol. ii. p. 84 (Syd. Soc. Ed.).
[3] *Op. cit.* p. 380.

for example, opium in mania, tetanus, or delirium tremens, and in cases of acute pain. In other diseases, on the other hand, certain drugs cannot be exhibited even in small doses without attendant harmful effects; as mercury in cirrhosis of the kidney, arsenic in chronic dysentery, opium to patients predisposed to apoplexy ; and in certain physiological conditions, as ergot, or large doses of quinine, in pregnancy.

8. *Sleep.*—That poisons seem to act more slowly during sleep is accounted for by the fact that absorption is then less active than during the waking condition ; otherwise, sleep has no special bearing on the activity of poisons.

9. *Idiosyncrasy.*—This is borne out in the case of persons who suffer severely from such doses of mercury or opium as would, in the average person, produce but little physiological result. In like manner, idiosyncrasy asserts itself with respect to certain articles of diet, as cheese, shell-fish, and others.

EVIDENCES OF POISONING IN THE LIVING BODY.

The evidences of poisoning will depend upon whether the act of poisoning is a single one, or a series of continuous periodic acts; or, as the attacks are sometimes denominated, whether the poisoning be acute or chronic.

(*a*) In acute poisoning the symptoms appear suddenly, while the individual is in good health. The person is seized with a group of symptoms of a definite character out of consonance with his previous state of well-being. This feature of the attack stands out prominently in all recorded cases of poisoning. At the same time, certain groups of symptoms of disease which simulate poisoning, may have a sudden onset, as cholera, gastro-enteritis, etc.

(*b*) In chronic poisoning, the onset of the symptoms is more gradual and insidious, because of the small quantity of poison which has been administered at each time ; for the intention of the poisoner may not be to kill his victim suddenly, but gradually by persistent administration of small doses of poison, in the hope of averting suspicion. In such cases, the possibility of detection lies in the want of causal relationship between the condition of the sufferer and the symptoms from which he suffers, in the fitful coming and going of the symptoms, in their appearance usually after food or liquids have been taken, and in their complete disappearance on the patient's removal from his usual surroundings.

(*c*) In acute poisoning especially, and in chronic poisoning generally, the symptoms appear soon after some kind of food or medicine, or drink has been taken. It must be recollected, however, that it is precisely under such circumstances that acute gastritis of an idiopathic character, perforation of the stomach, or other gastro-intestinal conditions may arise. In the case of Kate Dover tried in 1882, the symptoms of poisoning came on after dinner ; in the case of Madeline Smith, 1857, the symptoms were alleged to have come on after the victim had partaken of a cup of cocoa ; in that of William Dove, in 1856, after the victim had been given some medicine ; and

in the case of Dr. Pritchard, after various articles of food had been partaken of by the victim.

(*d*) Where more than one person has eaten of a similar dish, or of some article of food, and where they are similarly affected, there is strong presumptive evidence of poisoning. In Inverness, on Good Friday, 1882, several persons who ate hot cross buns made by one baker, were seized with symptoms betokening irritant poisoning. The Crown analyst, however, could discover no metallic irritant, but he found "an irritant alkaloid, of undetermined nature," which was supposed to be a constituent of the spice which had been mixed in the buns.[1] In the early part of the same year, in the village of Woodhouse, near Sheffield, 21 persons were attacked with the following symptoms, viz.: vomiting, diarrhœa, dimness of vision, and creeping feelings in the extremities, which continued for several hours. It was discovered that all those who had partaken of brawn, and only those, were attacked. No mineral poison was found on analysis, and it was believed that the illnesses were caused by some poisonous animal irritant due to decomposition of the brawn.[2]

(*e*) The strongest proof of poisoning, however, is established by the discovery of poison in the food taken, or in the vomited matters, especially where it can be shown that such could not have happened from accidental extraneous contamination.

If a poison be found in the urine of a patient suffering from unexpected and anomalous symptoms, there can be no doubt whatever that the poison has been introduced into the body, has passed into the circulation, and has then been excreted.

GENERAL LINES OF TREATMENT.

These may be summed up in a few sentences, and the mode and extent of their application must be left to the judgment of the practitioner in respect of the needs of individual cases.

First. Remove the poison from the stomach;

Second. Neutralise in the stomach what cannot be removed, or in the body by physiological antidotes what has been absorbed;

Third. Aid the elimination of the poison from the body by the natural channels; and

Fourth. Treat urgent and dangerous symptoms during and after the seizure.

The best means to remove irritant, mildly corrosive, and narcotic poisons from the stomach is the siphon-tube, which is easily introduced, and, when intelligently used, can do no injury. The best kind of tube is made of flexible Para rubber, tube and funnel being combined in one piece. It should measure in total length about five feet and be marked at a point 20 inches from the stomach-end, which should be of thicker rubber than the rest of the tube, for easier introduction, and should be perforated by more than one opening. For adults, a tube of half an inch diameter is a good size. For young children, a tube may be extemporised out of a soft rubber catheter, rubber tubing, a piece of glass tubing, and a small funnel. After warming the tube and

[1] *B. M. J.*, 1882, vol. ii. p. 284. [2] Idem, vol. i. p. 396.

anointing it with a lubricant, it is passed into the stomach by depressing the tongue with the finger, sliding the tube along the finger well back into the pharynx, and thus passing it downwards. When the mark on the tube is reached, the tube has entered the stomach. Warm water, at a temperature at which the hand can be freely introduced into it without discomfort, is then poured in by the funnel to the amount of about two pints, which water may contain a suitable dissolved antidote if such be available, the funnel all the time being held some distance above the patient's head. While the last portion of water is being poured in, and while the tube and a portion of the funnel is full of the water, the tube at its junction with the funnel is tightly pinched between the finger and thumb, and the tube is then lowered below the level of the stomach. Atmospheric pressure acting upon the column of water in stomach and tube will cause it to run out of both, and thus empty the contents of both. The operation may be repeated as often as is required. It may be necessary in some cases of determined suicide or in other contingencies, to use a gag for the mouth. In all cases of strychnia poisoning, it is imperative that before attempting to introduce the siphon-tube into the stomach, the patient should be put under chloroform, otherwise, the attempt will probably induce spasm, and frustrate the effort. Where a siphon-tube is not available, and since promptitude of action is all-important, the most easily procurable emetics, as mustard and water, or salt and water, should be freely used. Should the patient refuse or be unable to swallow, and if apomorphia be at hand, a hypodermic injection of $\frac{1}{20}$th to $\frac{1}{10}$th of a grain may be administered. It is a good plan, where the poison swallowed is known, to introduce a suitable chemical antidote dissolved in the water, such as permanganate of potash in opium or morphia poisoning in the proportion of 10 to 15 grains to the pint, and in poisoning by other substances, similarly suitable antidotes. The stomach siphon-tube ought not to be used in cases of poisoning by strong corrosives. In such cases, it is better, if possible, to counteract their effects by causing the patient to drink copiously of fluids charged with suitable antidotes. In poisoning by certain substances, as arsenic, cantharides, turpentine, and others, which by irritant action upon the kidneys develop inflammatory processes therein and thus prevent natural elimination of the poison, it is necessary to assist the excretion of urea by getting the skin to act. Perspiration may be induced by hot baths, warm packs, or by hypodermic injection of pilocarpine.

After recovery from the immediate effects of corrosive poisoning, it is necessary to prevent, if possible, cicatricial contraction of the gullet. This is effected by bougies carefully regulated as to size, and carefully used. In certain cases of poisoning by liquid ammonia or other corrosive which gives off fumes, laryngeal complications may be set up; it may become necessary, therefore, in order to prevent death by asphyxia, to perform tracheotomy. These, with rectal feeding, and the allaying of pain, constitute the main needs in cases of poisoning.

The Duty of a Medical Practitioner in Cases of Suspected Poisoning.—Suppose a medical man be called to a case which, from the symptoms exhibited, he suspects to be due to slow poisoning, what

points should he attend to, besides his duty in trying to ward off death? They may be comprehended in the following, viz. :—

(*a*) Note the time of occurrence of the symptoms, and their character;

(*b*) Note their relation in point of time to the last partaking of food, drink, or medicine ; and the order in which they appear.

(*c*) Observe whether the symptoms do or do not intermit, or increase steadily in severity.

(*d*) Inquire into the previous condition of health of the person attacked.

(*e*) If there has been vomiting, see the vomited matter, and, if possible, secure it for purposes of examination on some reasonable pretext, or note whether the vomited matters have been hastily disposed of.

(*f*) Secure a portion of food, drink, or medicine suspected, and samples of urine, for after-examination.

(*g*) If food or a particular dish is suspected, inquire whether similar food, or dish, has been previously eaten with impunity, and note, after inquiry, whether or not any other person than the one attacked has eaten of it with impunity, or has been attacked simultaneously.

(*h*) Take mental note of explanations offered or remarks made, regarding the onset of symptoms.

(*i*) Where the symptoms are not conform to the bodily condition, and where, in spite of appropriate treatment, they continue, narrowly watch the whole surroundings of the patient, and the conduct of those tending him.

EVIDENCE OF POISONING ON THE DEAD BODY.

1. *Evidence from Post-Mortem Appearances.*—The post-mortem appearances found will be considered in detail when the poisons are considered in groups or classes. It is sufficient to say that such precautions should be taken as are laid down in page 20. In conducting a post-mortem examination where poisoning is suspected—and especially where there is a possibility of a volatile odorous poison being found —it is very advisable that no odorous disinfectant should be used in the post-mortem room prior to the examination, lest the sense of smell be blunted. We are acquainted with the details of a case in which two medical men made an examination of the body of a woman which was found under suspicious circumstances, and where they failed to discover that death was due to carbolic acid,—owing to the fact, it was stated, that such a disinfectant had been used in the room before the examination was made.

2. *Evidence from Chemical Analysis.*—This is, *par excellence*, the most important proof of poisoning, when a poison is found in the contents of the stomach and intestines, in the substance of the internal organs, in the urine, or in one or other, or more than one of these. It may happen, however, in certain cases, that by reason of decomposition of the tissues of the body, and the lapse of time between the death and the examination, the poison may not be found on analysis.

This is possible, for example, in the case of hydrocyanic acid. Difficulties, too, may occur in cases where, with respect to the particular poison employed, there are no distinguishing chemical tests for its identity, as in aconitine. There are some medical jurists, however—the late Professor Christison, for example—who have held, and who hold, that if the symptoms, post-mortem appearances, and moral evidence are very strong, it is not necessary that the poison itself should be found, in order that a charge may lie, and a conviction be obtained. That, however, is a question which can only be decided in each individual case, and regarding which it is not advisable that a general rule should be stated.

Evidence by Experiments on Animals.—Such experiments either constitute the principal proof of the existence of a poison, or merely corroborative proof. Marshall Hall's test for strychnia by immersing a frog in the solution suspected to contain the poison, is one which would only be used as corroborative evidence, since the poison may be isolated from the bodily tissues by Stas', Dragendorff's, or Selmi's process. In the Lamson case, tried in 1881, where the poison used was aconitine, Dr. Stevenson had to fall back upon purely experimental evidence of this kind upon himself and upon mice, to distinguish the character of the alkaloid which he isolated from the body.

The late Mr. Montague Williams who conducted the defence, and who tried to establish that death was due merely to ptomaine poisoning, quoted Lord Coleridge to the effect that tests upon animals were most unreliable. Such an opinion even from such an eminent expert in law cannot be deemed as binding upon experts in medicine, and must, therefore, be taken for what it is worth. It is necessary to admit, however, that experiments upon certain animals with certain poisonous substances would be highly inconclusive, since certain animals are insusceptible to the influence of certain poisons which are inimical to man; for example, rabbits can live on the leaves of belladonna, hyoscyamus, and stramonium, and it has been stated by more than one observer that pigeons may take relatively large quantities of morphia without the poisonous effect being exhibited. At the same time, a cat or a dog will exhibit the same line of symptoms after swallowing prussic acid as a man; and so, also, with respect to other poisons. Therefore, when experiments upon animals are appropriately and properly conducted, they afford valuable evidence.

Moral Evidence.—A medical practitioner has usually little to do with this aspect of evidence, although he must not shut his eyes to what is going on around his patient, and he may be able to testify as to the truthfulness or correctness of statements made to him either by the person poisoned, or by some individual who is afterwards charged with the crime; for in this connection, it is undoubtedly his duty to play the rôle of detective as part of his duty of physician, in the sick room. It has been the lot of some practitioners to witness cases in which a patient's health was being undermined by the more or less regular administration of small doses of poison, and such is not unlikely at any time. What course, then, should a practitioner follow when he suspects such proceedings? He cannot speak of it openly,

because that would at once defeat his end, viz., the discovery of the actual fact, or it might expose him, if he did so prematurely, or, if having spoken out, his suspicions were ill-established, to an action for slander. On the other hand, if he allow matters to proceed without action of any kind, he may expose himself later to the censure of a Judge in open Court, or of the public. In the Pritchard poisoning case, Dr. Paterson, one of the witnesses for the Crown, who stated in the witness-box that he formed the opinion the first time he was called to see Mrs. Pritchard that she was being poisoned by antimony, was severely taken to task by the Lord Justice-Clerk who presided at the trial, in the following words: "He [Dr. Paterson] said, in answer to the questions put to him, that his meaning was—what he intended to state in the box was—that he was under the decided impression, when he saw Mrs. Pritchard on these occasions, that somebody was practising upon her with poison. Now, he thought it consistent with his professional duty, and I must also add, in his duty as a citizen of this country, to keep that opinion to himself. In that I cannot say that he did right. I should be very sorry to lead you to think so. I care not for professional etiquette, or professional rule. There is a rule of life and a consideration that is far higher than these—and that is the duty of every citizen of this country—that every right-minded man owes to his neighbour, to prevent the destruction of human life in this world, and in that duty I cannot say but Dr. Paterson failed." But it has been urged by some, that the proper course to pursue is that the medical practitioner should deliberately say in the presence of the suspected party what he believed was going on, and that if the condition of the patient did not improve that he would be bound to call the criminal authorities to his aid. This is a step, however, which could only be taken when poison had been actually found in the excretions of the patient. But in our view it is not the right step, because it may first of all lead to the dismissal of the medical attendant from the further treatment of the case, and the patient would thus be deprived of his knowledge; further, from the legal point of view, his conduct might be considered as compounding with crime. The best course, probably, to adopt, where poison is found as described, is for the medical attendant to call in, on his own responsibility, a colleague with whom he may consult, and, thereafter, determine to have the patient attended by skilled nurses, who alone should have the entire management of the patient, with regard, even, to the preparation of food, and its administration. Should these measures fail, then he ought to take the patient into his confidence, and by skilfully laid plans try to detect the source of the poison and the poisoner.

CLASSIFICATION OF POISONS.

By reason of the fact that poisons are so numerous, and their actions, individually, so different, it is necessary to reduce them to a system or classification. Various classifications, some of them more or less elaborate, have been made, and upon different bases. One classification has been established upon the sources of poisons, without respect to their action; another, upon their action, without respect to

their sources; a third, by reason of their action upon the different organs of the body; and so on.

For example, they have been divided into (*a*), mineral, (*b*), vegetable, (*c*), animal, and (*d*), mechanical agents. In another classification, they are grouped into three great divisions, viz.: I. Irritants, embracing Corrosives; II. Neurotics or Narcotics; III. Narcotico-Irritants. Again, they have been classified as to their action into two main divisions, viz.: I. Chemical. II. Vital.

I. Chemical.

1. Corrosives. { Acids, Alkalies, Caustic Salts.

2. Vulnerants: Glass; Needles.

II. Vital.

1. Irritant Metalloid	= Phosphorus, Iodine.
,, Metallic	= Arsenic, Antimony, Mercury, etc.
,, Vegetable	= Gamboge, Colchicum, Squill.
,, Animal	= Cantharides, Ptomaines.
2. Narcotic—Somniferous	= Opium.
,, —Deliriant	= Hyoscyamus, Bellodonna.
,, —Inebriant	= Alcohol, Chloroform, Ether, Cannabis Indica.
3. Sedative—Cardiac	= Digitalis.
,, —Cerebral	= Hydrocyanic Acid.
,, —Neural	= Aconite, Conium.
4. Excito-motory	= Strychnia, Ergot.
5. Toxæmic or Septic	= Snake poison, ptomaines.
6. Irrespirable Gases	= Carbonic Acid, Carbon monoxide, coal-gas, chlorine, etc.

Perhaps the simplest classification is that which is first given. But we do not propose to follow closely any of the above classifications, since all of them are too arbitrary, and some are not sufficiently practical.

I. The Mineral class lends itself to two subdivisions, viz.:—

1. The Corrosive Poisons.
2. The Irritant ,,

(*a*) General Action of Corrosives.—There is more or less destruction of parts with which the corrosive substance comes in contact; there is no remote systemic action, excepting, perhaps, shock; the symptoms come on immediately after swallowing, and consist of burning, agonising pain in mouth, throat, gullet, and stomach, continuous retching and vomiting of shreddy bloody matter; intense thirst; and, probably, some implication of air-passages. There will be signs of corrosion of lips, or mouth; usually, the mind is clear; death may be due to shock, to extensive destruction of parts, to suffocation from implication of larynx, to perforation of the stomach, or, later, to starvation from cicatricial contraction of gullet, or stomach, or both.

Post-Mortem Appearances.—These may be generally expressed as signs of corrosion and destruction of parts, varying in extent from localised patches to extensive destruction, particularly in the stomach.

(*b*) General Action of Irritants.—The symptoms come on at a variable interval after the poison has been swallowed, usually from a half to one hour thereafter. They are indicative of gastro-intestinal irritation, and consist of severe pains in stomach and abdomen, associated with, or followed by, violent, continuous and painful vomiting and diarrhœa. The vomited matter, at first consisting of the contents of the stomach, becomes bilious, and, later, is composed of "coffee-grounds" material. Along the track of the gullet there is a feeling of intense heat and, usually, of constriction, which provokes considerable thirst, to satisfy which by drinking only further provokes vomiting. The diarrhœa, consisting at first of ordinary loose stools, and afterwards of stools mixed with blood accompanied by tenesmus, is severe and urgent. After some time, the patient begins to show signs of collapse or shock ; the pulse becomes thready and irregular, and the skin clammy and cold ; cramps may appear in the muscles of the limbs ; and, although during all this time the mind of the patient is clear, before death unconsciousness, preceded or succeeded by convulsions, usually heralds the fatal issue. The period of death is variable, depending upon the amount of the poison swallowed, and the condition of the patient at the time. Death may be due to shock, shock combined with the effects of absorption of the poison into the system, or to protracted suffering from consequent inflammation of the gastro-intestinal tract.

Post-Mortem Appearances.—These consist of evidences of irritation, inflammation, and ulceration in stomach and intestines, and especially in the rectal portion of the bowel.

Corrosives.—I. The Mineral Acids.—The symptoms come on immediately ; there is violent burning pain, which extends from mouth to stomach ; gaseous frothy eructations ; brownish, or blackish vomit, mixed with coffee-grounds sediment, and sometimes, even with blackened or yellowish portions of mucous membrane. The vomit has a strongly acid reaction, stains clothes or carpet upon which it falls, and causes effervescence with a carbonate ; there is intense thirst, and the efforts to swallow in appeasing it are attended with great difficulty and pain ; there may be considerable dyspnœa, from swelling of epiglottis and mouth of larynx. The mouth and lips will be found excoriated, the mucous membrane of tongue and mouth, soft and pasty, and looking as if covered with a coating of paint, of different colour depending upon acid swallowed ; hence articulation is apt to be indistinct. If, however, the acid has been taken out of a spoon, or from a necked bottle, the lips may escape : the teeth may be loosened if the gums be much destroyed. The vomiting and retching being more or less constant, the patient becomes weaker, and although the mental faculties may remain clear till near the end, convulsions, suffocation, exhaustion, or shock from perforation of stomach, puts an end to the sufferings of the patient. Recovery may follow prompt antidotal measures, but death may eventually result, notwithstanding, from stricture of gullet or stomach.

Post-Mortem Changes.—Lips may be stained, yellow, whitish, or brownish ; the mucous membrane of mouth is corroded, the tissues being softened and discoloured ; the gullet is similarly affected,

although, here and there, may be found blackish areas and patches from altered, effused blood; the stomach is collapsed and contains a blackish, charred-looking material, or is covered by a yellow coating, and the mucous membrane thrown into corrugated folds; it may, or may not be perforated; if perforated, some of the acid will have escaped into the abdominal cavity, and will have acted upon the contents over a variable-sized area.

FIG. 95 shows the marks of corrosion round the mouth from the action of corrosive poison. The figure exhibits the appearances in the victim of the Oldham Case. The corrosive marks in this case were at each angle of the mouth, and involved the mucous membrane of upper lip and adjoining skin. The patch on the left side measured 1¼ inches in length and ⅓ of an inch in width; that on the right side being one inch in length and ⅓ of an inch in width. On the chin to the right of the median line and ¼ of an inch below the junction of skin and mucous membrane of lower lip was a dry corroded patch of skin circular in shape and ⅓ of an inch in diameter. Sulphuric acid is believed to have been the corrosive used.[2] (Photograph kindly lent by Dr. Harris.)

In dealing with such cases, it is necessary to bear in mind the post-mortem appearances of gastric ulcer, and of post-mortem digestion of stomach.

General Treatment. — The stomach-pump, or stomach-tube, should never be used, as they are dangerous. Alkalies — as lime, chalk, calcined magnesia, carbonates of the alkalies—mixed with water, and, later, diluent, demulcent drinks — as barley-water, milk, thin gruel—should be given freely.

I. **Sulphuric Acid.**—It is commonly used in certain trades, in the form of strong, and often, impure, vitriol. In dilute form, it is used in medicine, either diluted by itself, or in the form of aromatic sulphuric acid. A child who swallowed some of the acid, died in about 24 hours after.[1]

It may have to be examined in one of four conditions, viz. :—

(*a*) Concentrated acid;
(*b*) Dilute acid;
(*c*) Mixed with Vomited Matter or Contents of stomach;
(*d*) As Stains upon clothing.

A. CONCENTRATED ACID.

Tests.—

1. It chars organic matter, such as sugar.
2. When mixed with water, it evolves considerable heat.
3. When boiled with a reducing agent, as chips of wood, or copper foil, fumes of SO_2 are given off, which are detected by, (*a*), odour; and (*b*), by first making blue, and then bleaching, starch-paper dipped in iodic acid, or potassium iodide.

[1] *B. M. J.*, vol. i. 1881, p. 174.
[2] *Med. Chron.* (Harris), May 1887.

Hydrochloric Acid. B.M.J. Vol II. 1902. Two Cases. p. [illegible]

B. Dilute Acid.

1. When a drop or two of methyl-orange is added to some of the liquid, the yellow or orange colour is changed to pink or red.

2. If a solution of barium chloride be added after acidifying with dilute HCl, a dense white precipitate is formed, which is practically insoluble in boiling nitric or hydrochloric acids.

C. Mixed with Contents of Stomach, or in Vomit.

When filtered, the above tests may be employed.

D. Stains upon Cloth.

1. This acid changes black cloth to a dirty brown, which becomes reddened at the edges; the dilute acid gives a red stain, which in time becomes brown.

2. The stains remain long damp, the acid being hygroscopic.

3. Cut out stain; macerate in water; filter; apply Barium test.

4. Cut out similar-sized piece of unstained cloth, and treat similarly —for parallel test.

Post-Mortem Appearances.—Intense inflammation of stomach, the mucous membrane of which is blackened more or less extensively. From post-mortem diffusion, the corrosive action may be observed in the peritoneal cavity, and in consequence, the large intestine may share these appearances. The œsophagus may also, in parts, be blackened and eroded, and sloughs may be found in the larynx.[1] In one case in which a man took half a pint of the acid with suicidal intent, and from the effects of which death took place in two hours, the stomach was wholly destroyed, and the whole alimentary tract from mouth to rectum was changed. Owing to post-mortem diffusion, the acid had saturated the pericardium, surface of the heart, and neighbouring portions of lung and diaphragm, while all the abdominal viscera were hardened on their surface, and the abdominal muscles were saturated by it.[2]

Quantitative Analysis.—The total amount of acid present in stomach may be estimated by cutting up the stomach and contents, and macerating in water, which must be repeated as often as the fluid remains acid; then the combined macerations should be filtered, concentrated by boiling, and titrated, either *in toto* or in aliquot portion, by decinormal ($N\frac{1}{10}$) soda, potash, or ammonia, using methyl-orange as an indicator; or by precipitating the acid with $N\frac{1}{10}$ barium chloride in excess, and calculating the amount of acid in the dried and weighed precipitate of barium sulphate.

Fatal Dose.—Half a drachm has killed a child about one year old, in 24 hours. Christison states the smallest fatal dose in an adult to be ʒi. On the other hand, recovery has followed the taking of ℥iv.

Fatal Period.—Shortest, one hour; average, eight to sixteen hours. Death, however, may be instantaneous from shock, and life may be prolonged for weeks or months.

II. **Hydrochloric Acid**.—Spirit of Salt.—It is used in various trades. It may be found as follows:—

(*a*) Concentrated Acid.

(*b*) Dilute Acid.

(*c*) Mixed with Contents of Stomach, or with Vomit.

(*d*) Stains upon cloth.

[1] *B. M. J.*, vol. i. 1883, p. 255. [2] *The Lancet*, vol. i. 1879, p. 373.

1. Concentrated Acid.—*Characters:* it is either colourless, or of a pale lemon yellow colour, due to perchloride of iron; fumes in the air, and gives off dense fumes of ammonium chloride, in presence of ammonia.

Tests.—

(*a*) It tinges organic matter a light yellow colour.

(*b*) It does not act upon copper or mercury.

(*c*) When peroxide of manganese is added, and the mixture is warmed, chlorine gas, recognised by its greenish-yellow colour, and its pungent, suffocating odour, is given off, which bleaches litmus paper, and turns starch-iodised paper blue.

2. Dilute Acid.—

(*a*) When a solution of $AgNO_3$ is added, a precipitate, curdy in character, and white at first, but, later, becoming greyish in colour on exposure to light, is thrown down. The precipitate is soluble in NH_3, and is not soluble in HNO_3, as is the oxalate of silver.

3. Mixed with Contents of Stomach, or with Vomit.—

1. Test with methyl-orange for acidity.
2. Apply Silver test.

4. Stains upon Cloth.—From this acid, stains at first are of a bright-red colour, changing in about ten to twelve days to a reddish-brown.

1. Treat as before, and distinguish by negative responses to tests for other acids, and by positive silver test.

Post-Mortem Appearances.—The parts of mucous membranes which have come in contact with this acid are dirty-white or ash-grey in colour, which is, however, most marked in the gastric membrane. Although perforation of the stomach is not so frequently found as from sulphuric acid, it has, nevertheless, been met with in several cases. In such cases, the acid will be found to have attacked the abdominal viscera, more or less; but whether perforation takes place or not, by reason of post-mortem diffusion through the gastric walls, some measure of erosive action on the abdominal organs is likely to be found. In addition to the colour of the mucous membrane above named, patches of erosion, of varying depth, some of them blackish, or reddish in colour, are also likely to be seen on the gastric mucous surface.

Quantitative Analysis.—Macerate stomach and contents in distilled water repeatedly, until last washing is free from acid. Concentrate contents by evaporation. Then, either titrate against a $N\frac{1}{10}$ alkali solution, using methyl-orange as indicator, or precipitate as silver chloride, by using excess of silver nitrate, and calculate acid from precipitate.

Fatal Period.—From 4 to 30 hours.

Fatal Dose.—Half an ounce. Recovery has followed where two ounces have been taken.

III. **Nitric Acid, or Aqua Fortis.**—The strong commercial acid varies in colour from a pale-yellow to a deep orange, depending upon amount of impurity, the height of the colour being due to presence of peroxide of nitrogen. It produces yellow stains on organic matter, due to formation of picric acid, which are darkened by addition of an alkali. A woman, applying some strong acid to relieve toothache, in-

advertently swallowed a quantity, and died from the effects.[1] A man, a brassfounder, swallowed by mistake for beer a quantity of the acid, from the effects of which he died.[2]

1. Concentrated Acid.

Tests.—

(*a*) It evolves irritating fumes on exposure to the air.

(*b*) It stains organic matters yellow, for the reason given.

(*c*) When added to copper foil, dense reddish fumes, irritating in character, are given off, which redden but do not bleach litmus paper.

(*d*) If strong HCl and a fragment of gold leaf be added, and heat applied, the latter is dissolved.

2. Dilute Acid.

(*a*) Negative response to barium and silver tests.

(*b*) Concentrate by heat; add carefully Potassium Carbonate until solution be neutral; dip bibulous paper in solution, and dry; thereafter ignite, when paper will burn like touchpaper, due to presence of potassium nitrate.

(*c*) With strong H_2SO_4 and a crystal of green sulphate of iron, a dark ring is formed round the crystal.

3. Mixed with Contents of Stomach, or with Vomit.

Macerate stomach and contents with distilled water repeatedly, until washings are acid-free: filter; titrate solution, after concentration, against $N\frac{1}{10}$ solution of KHO, using methyl-orange as indicator.

4. Stains upon Clothing.

Macerate cloth in water, and add to solution some KHO—to form Picrate of Potash.

Fatal Period.—Death commonly occurs within 24 hours; it has, however, happened in $1\frac{1}{2}$ hours. On the other hand, life has been prolonged for months after the acute symptoms have passed off.

Fatal Dose.—Of the strong acid, the smallest fatal dose recorded is ʒij. The fumes of the strong acid have proved fatal, from accidental breakage in a room, laboratory, or other confined place[3] of large vessels containing the concentrated acid.

II. Corrosive Alkalies.

1. Caustic Potash.
2. Caustic Soda.
3. Caustic Ammonia.

The caustic alkalies are used for a variety of purposes in the arts and in processes of manufacture, and the last named, also for domestic washing purposes. Generally speaking, in poisoning, while acting corrosively, they play the part of the bases of soaps, the fatty acids of which are provided by the fat of the tissues.

1. **Caustic Potash.**—Cases of poisoning by this are comparatively rare. We have seen but one case, in which a man swallowed a quantity of strong solution of this substance in mistake for ginger-beer, and although he recovered from the acute symptoms, he suffered from some degree of œsophageal stricture during the few years he lived after-

[1] *B. M. J.*, vol. i. 1882, p. 235. [2] Idem, vol. i. 1883, p. 976.
[3] *New York Med. Record*, 1886; *Lancet*, vol. i. 1863, p. 311.

wards. While poisoning by caustic potash is rare, poisonous effects are more common from the use of concentrated solutions of the carbonate, or pearl ash. The symptoms, generally, are of the corrosive type, but are not so severe as after the use of the mineral acids. Swelling of the tissues with which the alkali comes in contact is likely to be marked and severe, and the surface of mouth, tongue, and lips becomes highly reddened and ulcerated or eroded. The vomited matter has an unctuous feel, due to the formation of a soap, and its reaction is markedly alkaline.

The post-mortem appearances are indicative generally of corrosion, but not so markedly as after the mineral acids.

Chemical Analysis.—The contents of the stomach feel soapy, and give a markedly alkaline reaction. In dealing with the vomited matters, or the contents of the stomach, for quantitative estimation of the alkali, it is best to macerate the organ and its contents in distilled water until the last washing is alkali-free ; then to filter the macerated fluids ; concentrate by evaporation ; and titrate an aliquot portion with normal sulphuric acid, using methyl-orange as an indicator ; and then to obtain amount of alkali present by calculation : one c.c. of standard H_2SO_4 = ·056 gramme of KHO, and ·069 gramme of K_2CO_3. The nature of the alkali may be tested by the flame test, or by testing with platinic chloride in an acid solution, when, if potash be present, a crystalline canary-yellow precipitate of the double chloride of platinum and potassium will be formed.

Fatal Period.—Death has occurred after a few hours. Not many fatal cases have been recorded.

Fatal Dose.—Very uncertain.

Treatment.—Dilute acids, and diluent demulcent drinks.

2. **Caustic Soda :** NaHO.—Commonly met with as washing soda, a mixture of the hydrated oxide and the carbonate.

The remarks made respecting Potash hold good also concerning this alkali.

3. **Caustic Ammonia.**—During the past six months, we have seen two cases of attempted suicide by drinking ammonia sold for domestic washing purposes. In both cases, which recovered, the symptoms of dyspnœa and dysphagia were very urgent, and the former were accompanied by some degree of cyanosis. In one of the cases—that of a young woman—the mouth and throat were corroded in patches, the tongue and pharynx were swollen, and after these symptoms had subsided under treatment, stricture of the lower third of the œsophagus took place, which, however, was overcome by the use of graduated bougies. In neither of the cases was the amount of fluid swallowed ascertained. We ascertained from analysis of a portion of the fluid left in the bottle from which the quantity had been swallowed, that the strength of the ammonia was 9·8 per cent. The liquor ammoniæ, fort., contains from 36 to 37 per cent. pure ammonia. In cases in which the primary effects are successfully overcome, death may happen some months later from stricture of the gullet. In one case, death followed three months later from this cause.[1] The urgent symptoms in poisoning by ammonia are

[1] *Med. Times and Gazette*, Nov. 1853, p. 554.

due to the involvement of the air-passages. Cases have been put on record where, by reason of the bursting of vessels containing ammonia, workmen have been enveloped in the fumes from which they have died. In Glasgow, in Sept. 1898, an ammonia cylinder burst in a cold storage works, whereby the manager and two workmen lost their lives. The two men, on being rescued, were found to be suffering from great swelling of fauces, uvula, tongue, and lips, with congestion of conjunctivæ. The epithelium of mouth and palate was destroyed by the caustic action of the ammonia. Both suffered before death, which took place on the third day, from capillary bronchitis. The post-mortem appearances seen were as follows:—a raw, inflamed condition of fauces, uvula, tonsils, and tongue; the bronchi were covered with a fibrinous membrane which was easily stripped, leaving a raw surface beneath; the larynx, trachea, and finer bronchioles, were likewise covered with this false membrane. The lung substance, on microscopic examination, showed the presence of a very evident broncho-pneumonia, marked hyperæmia and thickening of the walls of bronchioles, and the presence in the alveoli of a fine reticulum of fibrin, containing leucocytes and catarrhal cells. The blood generally was dark in colour, and was imperfectly coagulated. Death was due to asphyxia.[1]

In 1900, another fatal case of poisoning by the fumes of ammonia occurred in an ironwork in Glasgow — in a man who was engaged cleaning a still in connection with an ammonia boiler. He was unconscious when found, and shortly thereafter died.

Serious symptoms of poisoning have also followed the swallowing of the carbonate. In one case recorded by Taylor, where ʒv of *sal volatile* were taken, the patient was comatose within ten minutes after, but he eventually recovered.

Fatal Period.—Shortest period known is four minutes.

Fatal Dose.—ʒi., and upwards of strong ammonia.

Chemical Analysis.—The qualitative examination for this substance may be performed by Nessler's test, which gives in very dilute solutions a markedly dark orange-red precipitate. To make a quantitative estimation, the stomach and its contents may be distilled into a receiver containing a definite quantity of Standard Sulphuric Acid, and by titration backwards, the amount present may be arrived at very easily.

Corrosive Organic Acids.—

Oxalic Acid.—This acid is used in the arts by shoemakers, bookbinders, brass polishers, straw-hat makers, and the oxalate of potash, by washerwomen, for taking rust stains out of linen. It is sometimes taken with suicidal intention, has occasionally been mistaken for Epsom salts, and fatal results have ensued in both classes of cases.

Symptoms.—If a large dose of the acid be taken, the following symptoms are commonly found, viz.: a burning, acrid taste on swallowing; vomiting which is severe and continuous; burning sensation in gullet and stomach; occasionally, a sense of suffocation, with lividity of countenance, and hurried respiration; anxiety of counte-

[1] Workman and Monro, *Glasg. Med. Jour.*, vol. ii. (Nov.), 1898.

nance; the skin cold and clammy. In one case, the vomiting continued until the fifth day, when death took place suddenly;[1] and in another, recorded by Christison, the vomiting did not supervene until seven hours after swallowing, the acid in this case having been much diluted. The vomited material may, at first, consist only of the contents of the stomach and of large quantities of mucus, but, sooner or later, it becomes of a greenish-black, or nearly black colour, resembling thick coffee-grounds consisting of mucus and altered blood. In addition to the foregoing symptoms, there are great pain and tenderness of the abdomen, so much so, occasionally, that the patient lies doubled up. If the case be short in duration, the bowels are not affected, but if it be prolonged, purging and tenesmus may be present. The pulse becomes feeble, small, and irregular, and, not infrequently, the patient complains of a sensation of numbness in the limbs. Convulsions often precede death. It may be stated, in brief, that the symptoms depend upon two factors: (1), the amount of the acid taken, and (2), the concentration or dilution of the acid fluid swallowed. When in concentrated solution, the acid acts as a corrosive.

Post-Mortem Appearances.—If the dose be large and the acid concentrated in the vehicle swallowed, all the parts which have come in contact with the acid are softened and white—corroded, in short—or stained with blackish or reddish streaks. The stomach contains a dark-brown, glairy fluid, which has an acid reaction. The mucous membrane of this organ is corroded to a greater or lesser extent, and underneath it, the blood-vessels may be distinctly seen because of their dark-coloured contents. The membrane may not be much corroded if death be rapid. Perforation is rare, but it has been found. Moore describes the condition of the stomach of a woman, aged 24, who had taken several ounces of the acid, and had died *four* hours after. The epiglottis, fauces, and pharynx were pink and grey in tint, the lower part of gullet, grey, the mucous membrane detached in parts, and everywhere wrinkled. The stomach was distended with dark blood, but there was no abrasion. The mucous membrane generally was of a brownish colour, with darker lines along the course of the vessels.[2]

Fatal Dose.—A boy of sixteen died in eight hours after a dose of 60 grains.[3] Recovery, however, has followed the swallowing of half an ounce, and $1\frac{1}{2}$ ounces,[4] respectively, after prompt and active treatment.

Fatal Period.—The shortest period recorded is that by Dr. Ogilvy of Coventry, viz.: three minutes. Death took place in a second case in ten minutes, after one ounce had been taken; in a third, at the end of thirty minutes, from the same dose; while a person has survived for five days.

Treatment.—Consists in the use of chalk, whiting, or lime, with milk, or other demulcent drinks, and in small concentrated quantities.

Chemical Analysis.—If the vomited matter or contents of the stomach be examined, and if they be found highly acid filter; if not very acid, boil with distilled water before filtering, and concentrate by evaporation. To the filtered liquid, add acetic acid and acetate of

1 *Lancet*, vol. ii. 1860, p. 509.
2 *B. M. J.*, vol. i. 1882, p. 740.
3 *Lancet*, vol. ii. 1855, Dec. 1.
4 *B. M. J.*, vol. i. 1881, p. 640.

lead till precipitation ceases; collect precipitate and wash. The precipitate will consist of oxalate of lead. Then diffuse the precipitate in distilled water, and pass through it a current of H_2S, which throws down lead sulphide; filter to remove precipitate; heat, to expel excess of H_2S, and concentrate solution by evaporation on a watch-glass, when the crystals will form out; these can be dissolved and tested by liquid tests. Dialysis may be used here to advantage. The contents of the stomach, or vomited matter, are put in the dialyser placed in distilled water, and the acid will pass through the membrane. The dialysate may then be concentrated, and the crystals evaporated out.

Oxalate or **Binoxalate of Potash**—salts of sorrel, or salts of lemon—is an acid salt, used for removing iron stains from clothing, and, therefore, may be accidentally or suicidally taken. It may

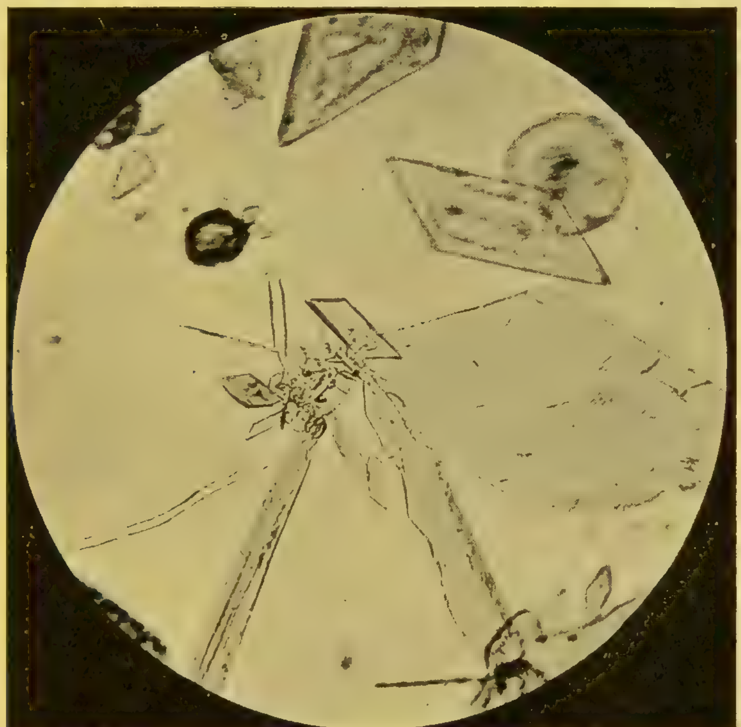

FIG. 96.—Photo-micrograph of crystals of Potassium Binoxalate. × 500 diameters. (Author.)

practically be deemed to be as poisonous as the acid itself. In one case where about half an ounce was taken by mistake for Rochelle salts, the patient was seized with acute symptoms of poisoning within three minutes after, viz.: severe burning pain in gullet and stomach, vomiting of a brownish tough mucus, and partial unconsciousness; and later, with purging, and severe pains in loins and back. He recovered.[1] The same dose, however, proved fatal in another case. One case recovered, under prompt treatment, after one ounce had been taken.[2] Where part of the contents of the packet are available for

[1] Park, *Glas. Med. Journal*, vol. xxxii. p. 179.
[2] *Med. Times and Gazette*, vol. xxvii. p. 480.

"A case of Creasote Poisoning in a child" (Cowan) [illegible] 1897.

geal complications, because of the volatility of the acid, are commonly found in such cases. The action, locally, is therefore that of a corrosive, and such effects are apparent in the mouth.

Post-Mortem Appearances are those of a corrosive; the mucous membrane of gullet and stomach will be found more or less attacked, and there may be appearances of corrosive action, certainly of inflammatory action, in the upper air-passages.

Fatal Period is variable, but rapid.

Fatal Dose.—ʒi. of the glacial acid killed a child; but an adult has recovered after taking six fluid ounces.

Carbolic Acid, or Phenol, (C_6H_5OH).—This substance is obtained by the action of nitrous acid on aniline, by the dry distillation of salicylic acid, and by the dry distillation of coal. Its use is familiar to the lay public as a popular disinfectant, and of late years, by reason of its facility of purchase and its common use, has given rise, suicidally and accidentally, to more deaths than any other poisonous substance. Up till the year 1900 this acid was promiscuously sold by drysalters, oilmen, and other tradesmen, without any restriction, but owing to the large number of deaths from its use, suicidally and accidentally, action was initiated by the Privy Council whereby it became a scheduled poison. The Act of Parliament enacts that carbolic acid, cresylic acid, and all preparations of these substances, or their homologues which contain more than 10 per cent. of these acids and which are used as disinfectants, must, hereafter, be sold as poisons, and with the same restrictive care as those poisons scheduled in former Pharmacy and Sale of Poisons Acts.

When pure, the acid consists of long, colourless, prismatic, needle-like crystals, which melt at 42° F., and boil at 108° F. It possesses a burning sweetish taste. It is slightly soluble in water (1 in 11), but is freely soluble in glycerine, ether, alcohol, benzene, etc. Although called an acid by reason of the form of its composition, unlike other acids it does not redden litmus paper. In concentrated form, it coagulates albumen. If the pure crystals are exposed for some time to the air, they become of a pinkish-red colour, due, it is believed, to their partial conversion into rosolic acid. For sanitary purposes, however, it is usually sold in a much cruder form, as a dark-coloured liquid more or less resembling porter or stout, which, like the purer forms, possesses a characteristic pungent, penetrating odour, but which consists of a mixture of carbolic acid, cresylic acid, and other derivatives, as ortho-, meta-, and para-cresol. These preparations are sold as Jeyes' Disinfecting Fluid, Creolin, Izal, and as other compounds. Carbolic acid acts as a mild corrosive upon the skin and mucous membranes, when in the crystalline form or in strong solutions. It gives a white, bleached, and puckered appearance to the skin at the point of application, the epidermis is destroyed, and a yellowish-brown, or brown appearance or staining results. Upon mucous membranes it produces a white coating, or ashy-grey or yellowish appearance.

Symptoms.—An intense burning pain in mouth, throat, and stomach; vomiting, which may be neither severe nor continuous, of frothy mucus; coldness and clamminess of skin; contraction of pupils; lividity of lips; stertorous, hurried, or laboured breathing;

small, thready pulse; subnormal temperature; early onset of insensibility. In many cases, the odour of the acid may be detected in the breath, though not in every case.[1] There may be signs of corrosion of the lips, corners of the mouth, or lower lip, the marks showing a pale-brown or yellowish colour. These, however, may be absent in suicidal cases, where the poison is swallowed from a long-necked bottle, or where the vessel is put well back into the pharynx. We have seen this in one case. The symptoms depend in some measure upon the concentration of the poison swallowed; if a strong solution (60 to 90 per cent.) is taken, death may follow quickly, with or without vomiting, and with rapidly intervening coma, and stertorous breathing; if a dilute solution, however (1 to 3 per cent.) be taken, the symptoms supervene only after absorption, are not usually so rapid in onset, and consist of prostration, unconsciousness, etc. It is to be borne in mind that owing to the local anæsthetic action of this acid, symptoms of irritation, as pain and vomiting, are not nearly so prominent as in poisoning by oxalic acid or the mineral acids.

From the foregoing, it will be apparent that carbolic acid has both a local and a systemic action, and that the symptoms will depend upon two main factors, viz.: (*a*), the concentrated or diluted state of the poison taken, and (*b*), the amount absorbed into the circulation.[2]

Post-Mortem Appearances.—Those parts of the skin surrounding the mouth, and the mucous membrane of lips and buccal cavity, with which the poison has come in contact, are stained of a pale-brown or yellowish-brown colour. But this effect entirely depends upon the strength of the poison; for example, a one per cent. solution produces no effect whatever, a two per cent. a slight staining, only observable on careful examination, a four to five per cent. solution, a whitish discoloration which is likely to disappear within six hours, whereas a strong solution of the acid or the pure acid itself, causes a white slough which lasts for a long time. Where impure carbolic solutions are swallowed, the colour of the stain will be more or less affected. The mucous membrane of gullet and stomach are also more or less similarly attacked. the latter, chiefly, doubtless owing to the longer period of contact; indeed, the action of carbolic acid upon the stomach membrane may be said to be characteristic, as it is corrugated, thrown into projecting folds or wrinkles, which have a more or less brownish colour, and which look as if they had been tanned. On opening the abdominal cavity, the odour of phenol can be usually detected easily, owing to the fact that after death some of the acid passes through the walls of stomach. For this reason, the peritoneal covering of stomach and of upper intestines is found injected. The odour of the acid is, however, most marked on opening the stomach, and its contents may be found to consist of blood-stained mucus. The lungs and brain are usually found congested, owing to the proximate cause of death.

But death may result from carbolic acid by absorption through the medium of the unbroken skin. At an inquest held in London into the circumstances attending the death of several sailors resulting

[1] *B. M. J.*, vol. ii. 1896, p. 507.
[2] *Vide* Lewin, *Deut. med. Woch.*, Ap. 21, 1898.

from the bursting of some casks of crude carbolic acid, Dr. Dupré stated as his opinion that the immediate cause of death was absorption of the acid through the skin. This is questionable, as the cause may have been the inhalation in a confined area of the fumes of the acid.[1] It appears that the men who died had been sent into the hold to secure the rolling casks, that they were severely burned, although not to a degree to cause the deaths, which occurred very suddenly, shortly after the incident.[2] Moreover, in the days of the early Listerian treatment of wounds by carbolic acid, many cases of poisoning were recorded, due to absorption of the poison in the wounds and by the skin from the surgical dressings, the main symptoms being signs of shock and carboluria.

Fatal Dose.—One drachm has killed in twelve hours.[3] Prof. Lewin, who was consulted in a case, stated as his opinion, however, that a man could not be fatally poisoned by one gramme of carbolic acid. This was a case in which a man died after exhibiting certain indefinite symptoms. On analysis, 0·6595 gramme of carbolic acid was found in the contents of stomach. On exhumation of the body eleven days after, the kidneys, brain, and liver were further examined, and an additional amount of the acid was found, sufficient to increase the total quantity found in the body to one gramme. Lewin admitted, however, that death from carbolic acid might occur by the direct action of the poison on the nervous system, but he did not believe that the quantity found in this case would be sufficient. Lewin, in his *Toxicologie*, gives the fatal dose as 8–60 grammes. Recovery, however, has followed the swallowing of large doses; in one case,[4] from one ounce of 90 per cent. phenol, in another, of a girl of 17, where six ounces of crude carbolic acid were taken,[5] and in a third, of a child of two, from half an ounce of crude acid containing 30 per cent. carbolic acid.[6]

Foulerton records a very interesting case of a watchman who mistaking crude carbolic acid for tea, swallowed about three ounces of it. The acid contained 90 per cent. of pure carbolic acid. He died within an hour. It appears that on discovering his mistake he informed a fellow-workman, who assisted him to hospital, which was about a quarter of a mile from the works. On his arrival there—about twenty-five minutes after the acid had been swallowed—he became unconscious, and died twenty minutes later.[7]

At the Calcutta Criminal Sessions, April, 1884, a medical practitioner was tried and found guilty of having caused the death of a child by administering an enema of carbolic acid—containing 200 drops of Calvert's No. 2 acid—for worms. Collapse followed immediately after the injection, and the child died in a few hours. The practitioner was fined 500 rupees for his rash and negligent act.

Recovery has also followed, after prompt treatment, the swallowing of about a pint of *Jeyes' fluid.* A man attempted to commit suicide in this way, and on his recovery, expressed regret that he had not succeeded.[8] *Izal*, which is an oily substance obtained from certain

1 *Vide B. M. J.* (Unthank), 1887.
2 *Med. Press*, vol. i. 1901, p. 694.
3 *Deut. med. Woch.*, Ap. 21, 1898.
4 *The Lancet*, 1891 (Greenway).
5 Hind, *The Lancet*, 1884.
6 Oliver, *B. M. J.*, 1884, vol. i. p. 356.
7 *The Lancet*, vol. i. 1889, p. 115.
8 *B. M. J.*, vol. i. 1901, p. 1618.

coke ovens, and which forms a creamy emulsion with water, has a faint odour of phenol. By the manufacturers it is claimed to be non-poisonous. Klein's experiments on rabbits, in which this substance was administered hypodermically and by the mouth, do not appear to us to be conclusive of its non-poisonous properties. Hobday[1] asserts that toxic symptoms follow the use of Izal if used injudiciously. Having used it as a dressing to the skin of dogs and cats, he found that the following toxic symptoms were produced, viz.: subnormal temperature, continual irritation, involuntary muscular twitchings, followed by complete inability on the part of the animal to rise, coma, and death. In like manner, *Creolin*[2] and *Lysol* may produce toxic effects. A case of fatal poisoning by the latter has been recorded.[3] A boy of 14, suffering from dysentery, took an injection of rather less than 1½ ounces of lysol in about a pint of water, at 1 P.M.; he was found in bed quite unconscious half-an-hour later, suffering from all the characteristic symptoms of poisoning by carbolic acid. He died at 5.45 P.M.

Kluge[4] has collected together 13 cases of lysol poisoning, four of which were due to its external application, and nine to its internal use. He narrates the facts of a case in which a nurse gave, by mistake, to an adult female patient who was suffering from enteric fever, some 12 grammes of lysol, of which 10 grammes were swallowed. In five minutes afterwards, the patient was cyanosed and in a state of stupor; the pulse could not be felt. After the stomach was freely washed out and camphor injected, she improved, and in three and a half hours after the administration of the lysol, she became conscious, and complained of burning in the mouth. She eventually recovered. Kluge is of opinion that the toxicity of carbolic acid is eight times greater than that of lysol. Stille-Ihlienworth[5] records toxic effects to have been produced in several persons by inhalation of creolin vapour. Burgl[6] gives two additional cases of lysol poisoning. Lysol is a compound made of equal parts of cresol and linseed oil potassium soap. Cresol is methyl-phenol. The first case by Burgl was that of an infant of five days old who was given a coffee-spoonful of lysol in mistake for syrup of rhubarb, of which it died in 14½ hours after. The second case was that of a girl, 8⅓ years of age, who had been given ʒi. of lysol in mistake for infusion of ipecacuanha, and who died in a few minutes thereafter.

Fatal Period.—Usually death follows from Carbolic Acid within three hours after the poison has been taken. It has, however, followed in three minutes, and it has been retarded until sixty hours after.

Treatment.—In view of the anæsthetic action of the poison, ordinary emetics may fail to act; at the same time, in the absence of more certain appliances for emptying the stomach, they must be tried. But the best treatment is to wash out the stomach with the aid of the siphon tube, using great care in its introduction, until the washings cease to smell of the acid. It is also a good plan to dissolve magnesium sulphate in the ingoing warm water, so that the benefit of whatever

1 *Journ. Comp. Path. and Therap.*, Sept. 1900.
2 *Vide* Pinner, *Deut. med. Woch.*, 1895; *The Lancet*, vol. i. 1896, p. 1732.
3 *B. M. J.*, vol. ii. 1900, p. 1497.
4 *Münch. med. Woch.*, July 12, 1898.
5 *Memorabilien*, July 1889.
6 *Münch. med. Woch.*, Sept. 24, 1901.

antidotal effect this salt may have should be secured; for it has been observed that in cases of carbolic acid poisoning, sulphates disappear from the urine. In view, also, of the condition of shock, the patient should be surrounded with warming-pans or bottles to restore the bodily heat. After preliminary recovery, rectal feeding should be adopted for some days.

Chemical Analysis.—The odour of the acid in the stomach contents points to its presence; but in order to detect it by chemical tests, it ought to be separated from the stomach contents, either by shaking them up with ether and siphoning off the supernatant fluid which contains the carbolic acid, or by slightly acidulating the contents with dilute sulphuric acid, and distilling. In the distillate, the acid will be found. The following tests may then be employed:—

1. *Landolt's test.*—To a portion of the ether solution, or distillate, add a few drops of Bromine Water. A whitish, or yellowish-white precipitate of tri-bromo-phenol ($C_6H_2Br_3OH$) will be formed. Collect the precipitate, wash it, and gently heat it in a test-tube with sodium-amalgam and water; thereafter pour the mixture into a large watch-glass and acidulate, when the characteristic odour of phenol will be given off.

2. To a second portion, add dilute ammonia and a few drops of 1 to 20 solution of freshly-made bleaching-powder; heat; a bluish or greenish coloration (depending upon degree of dilution) will be formed, which, on being acidulated, will be changed to red or yellow.

3. To a third portion, add a few drops of Ferric chloride (the perchloride of the B. P. will do), when a violet colour will be produced.

Quantitative Examination.—Landolt's reaction may be utilised as a means of estimating quantitatively the amount of acid present. If the whole of the acid be precipitated by bromine water, the precipitate, after being washed and dried, may be weighed. The amount of phenol is estimated by the fact that 100 parts of the tri-bromo-phenol are equivalent to 28·39 parts of phenol.

Caustic Salts.—There are certain salts of different elements which possess caustic properties, viz. of Antimony, Copper, Silver, and Zinc, and compounds of Chromic acid.

The Chloride or Butter of Antimony ($SbCl_3$), used for certain trade purposes, has been taken both accidentally and for suicidal purposes. It is a light-brown, dark-brown, or dark-red coloured liquid, and possesses marked caustic properties; indeed, the symptoms produced are more markedly those of a corrosive than of an irritant. In the few cases which have been recorded, the prominent symptoms were persistent vomiting, severe burning pain in mouth, throat, gullet, and stomach, and general signs of collapse.

Post-Mortem Appearances.—Evidence of corrosion of parts with which the poison has come in contact, with denudation of mucous membrane.

Fatal Dose.—Not very well known. Taylor records a case in which an army surgeon suicidally took from two to three fluid ounces, and died. A boy of ten years, however, has recovered from about half an ounce. For other cases, consult *Prov. Med. Journ.*, December 23, 1846; *The Lancet*, February 26, 1848, p. 230; Idem, May 19, 1883.

Sulphate of Copper ($CuSO_4$) in the solid form, or in very concentrated solution, exercises a limited corrosive effect, but its action is mainly that of an irritant. (*Vide* also p. 438.)

Zinc Chloride ($ZnCl_2$), as a solid, or in concentrated solution, also acts corrosively. It is the chief ingredient in the disinfecting solution known as "Sir J. Burnett's Fluid," which contains about 350 grains to the ounce of water. In several of the cases recorded in which this substance caused death, corrosion of the stomach has been found.[1] The symptoms are chiefly those of a corrosive poison.

This salt is sometimes used to "load" textile fabrics. In December, 1898, a number of men employed to clean the streets of Birmingham after a snow-storm, and who were provided with overcoats, were admitted into the hospitals suffering from large patches of sloughing skin of the wrists and knees. Upon inquiry, it was found that these effects were caused by the presence of considerable quantities of zinc chloride in the overcoats, and that the localised results were due to the dripping of the wet garments at the places named. It was shown at a meeting of Bradford cloth manufacturers that an 18-oz. worsted coating might be found to contain two to three ounces of zinc chloride.

Silver Nitrate ($AgNO_3$) likewise is corrosive, both in the solid and liquid form. One case is recorded, with a fatal result, in which a piece of solid stick nitrate became lodged in the throat while the tonsil was being cauterised.

Chromic Acid and the **Chromates of Potash** and **Soda** are also corrosive in action in the solid and concentrated liquid forms. Diluted, they act as irritant poisons, having, it would appear, special action upon the nervous system. In chrome workers, the caustic action is particularly seen in destruction of the nasal septum, and the formation of deep ulcers upon the hands, called "chrome-holes" by the workmen. For cases, consult the following references: White, *University Med. Mag.*, 1889; *B. M. J.*, 1889 (Fowler); *B. M. J.*, 1888 (Stewart); *The Lancet*, 1892; (Turnbull) *B. M. J.*, vol. i. 1881, p. 481 (where a child of two died from eating a piece of bichromate of potash, size of a pea). Hermann[2] affirms from observations made on 257 persons, workers in chrome-works, that chromic acid and the chromates exercise both direct and indirect action; the former characterised by the nose and skin lesions referred to, and the latter by causing lesions in stomach, respiratory tract, and kidneys. Of 77 workers employed for not longer than one month, 34 remained healthy, 32 had nasal abscess, and only one, perforation: of 39 who had worked longer than three and less than six months, 2 were healthy, 14 had abscess, and 23, perforation; and of 31 who had worked for more than a year, none were healthy, 7 had abscess, and 24, perforation. It would, therefore, appear that six months' employment in a chrome-work is likely to lead to nasal septum perforation in the bulk of those employed. Smith[3] records the symptoms of lead poisoning in several female mill-workers, from working with an orange-coloured cloth containing bichromate of lead.

1 *Med. Times*, July 13, 1850, p. 47; *The Lancet*, vol. ii. 1857, p. 271.
2 *Münch. med. Woch.*, Ap. 2, 1901.
3 *B. M. J.*, vol. i. 1882, p. 8.

CHAPTER II.

IRRITANT POISONS.

Arsenic.—This poison is found existing in nature as a metal, and as sulphides of the metal, realgar and orpiment, and can be purchased in these crude forms in native Indian bazaars; in flues, as arsenious acid, from the calcining of ores containing arsenic, the arsenic being deposited in a cool part of the flue. In Cornwall, for example, where *mundic*—an ore containing arsenic, tin, copper, and sulphur—is roasted, the arsenic is the product aimed at. With the metallic form the medical jurist has little to do, although it is stated that a fly-powder, which is sold in shops, contains the poison in the metallic form as well as in that of arsenious acid.

Arsenious acid, or white arsenic, is the substance most commonly employed in homicidal poisoning. As met with in commerce, it is either in the form of cakes, broken lumps, or a white, gritty powder. The lumps, at first, look almost transparent and crystalline, but later, they become opaque like enamel, and the fracture-surface takes a porcellanous appearance. According to Act of Parliament, arsenious acid cannot be sold in smaller quantity than 10 lbs., without being mixed with either soot, charcoal, or indigo in the proportion of one ounce of the two first named and half an ounce of the last to the pound of arsenic, and therefore, when it is sold by a pharmaceutical chemist it looks like a dark-grey, or bluish powder. It may, however, when unadulterated, give rise to accidental poisoning, by being mistaken for granulated sugar, or other like substance. A case was reported from the Bristol Royal Infirmary[1] in which powdered arsenic was mixed in a meat-pudding, which, after having been partaken of by several members of a family, caused them all to be seriously ill. One of them, a child of five years, died, the rest recovering after longer or shorter illnesses. Post-mortem examination of the body of the child showed in the stomach a brightly injected patch about the size of a shilling on the posterior wall, several punctiform hæmorrhages here and there in the mucous membrane, and reddened patches in duodenum, lower part of descending colon, and upper part of rectum. Chemical examination of the remains of the meat-pudding showed that it contained a large quantity of arsenic.

Physical Properties—(*a*) *Solubility.*—Arsenious Acid is very insoluble in water. Cold water will only dissolve one-half to one grain per ounce, and the solution thus obtained gives a faint acid reaction with litmus paper. When arsenious acid is mixed with boiling water and is boiled for some time, about 55 grains per ounce will be held in solution so long as the water is hot, but after the water has become

[1] *The Lancet*, vol. i. 1879, p. 699.

cold only about 12 grains per ounce remain dissolved, the remaining 43 grains being deposited in the vessel. By reason of this insolubility; when the fine powder is placed in water or other liquid, some of it forms a whitish film on the surface of the fluid, and the heavier particles fall to the bottom of the vessel. (*b*) *Effect of Heating.*—If some of the powder is placed on a platinum spatula and heat is applied to the under surface thereof, the powder will completely disappear in white fumes without the spatula becoming blackened, and without leaving any residue behind. If a cold piece of glass be held a little distance above the spatula, the white fumes will sublime on the glass, and, on examination by a hand-lens, the sublimate will be found to consist of crystals of the octohedral type.

Uses in the Arts.—It is somewhat extensively used in the arts; in dyeing, artificial flower-making, and taxidermy, in paper-making, for ornamental cards, and for wall-paper hangings. (*Vide* Fig. 97.) Murrell has demonstrated that out of seventeen different kinds of paper-wrappings of cigarettes and tobaccos, arsenic was present in the labels of six; that is, one-third.[1] It ought to be borne in mind that arsenic is not confined to wall-papers which are green in colour, and that although it is not so commonly used for this purpose as it used to be, there is no law in Great Britain, as there is in Germany, to prevent its use. It is used in medicine, also, for a variety of purposes. It is sold as a constituent of vermin-killers and of fly-papers, and it has been used as an adulterant of violet powders. In medicine, and in fly-papers, the arsenic usually exists in the form of sodium or potassium arsenite, since arsenious acid is soluble definitively in alkaline solutions. Fatal toxic effects may also be produced by arsenic in the gaseous form of Arseniuretted Hydrogen.

Cacodylic Acid and **Cacodylates** are also poisonous. Cacodylic Acid, or dimethyl-arsenic acid, $As(CH_3)_2O(OH)$, consists of oblique rhombic crystals, which dissolve very readily in water and alcohol, and melt at 200° C. The acid unites with various metals as sodium, lithium, calcium, magnesium, iron, mercury, and with other substances, as quinine, guaiacol, etc. According to several observers, it is comparatively non-poisonous, but this statement has been traversed by Murrell,[2] who affirms that the symptoms resulting from the administration of "cacodylate of sodium are far more severe than those which follow the exhibition of arsenic in its ordinary forms." According to the former, cacodylates, although comparatively rich in arsenic, are relatively inactive. It was, therefore, believed that such compounds could be exhibited with great benefit to patients in larger doses than the more usual arseniferous preparations. Professor Fraser of Edinburgh,[3] starting from the proposition that if such arsenical compounds are incapable of producing toxic effects when exhibited in such relatively larger amounts, assumed that they must therefore be pharmacologically inert and therapeutically inefficient. He tested this assumption, however, by clinical observations and by chemical tests. In a series of cases, he showed that arsenic administered as cacodylates

1 *B. M. J.*, vol. ii. 1896, p. 96.
2 Idem, vol. ii. 1900, p. 1823; vol. i. 1901, p. 120.
3 Idem, vol. i. 1902, p. 713.

"The decomposition of Compounds of Selenium & Tellurium by Moulds and its influence on the biological Test for arsenic. (Rosenheim)
Proc. Chem Soc: Vol 18. No. 253 (1902). p. 138.

is less therapeutically active than when administered as liquor arsenicalis. He found that the arsenic in the former preparations is united to the bases as arsenic acid, and that cacodylates failed to give the usual reaction with silver nitrate; further, that when Marsh's process was employed for the detection of arsenic in the urine of persons to whom Liquor Arsenicalis had been administered, the arsenic could be detected, but when cacodylates had been given, that the process failed to detect the arsenic. He concluded, therefore, that the arsenic in cacodylic acid and cacodylates is so firmly bound chemically to the base that even after absorption into and elimination from the body this stable chemical union is not dissociated, and the arsenic passes through the body as an inert substance without exercising much or any pharmacological activity.

Chronic poisoning may result from persons occupying rooms the walls of which are covered with paper containing arseniferous pigments. The mode by which the poison enters the body was, for a long time, the subject of much dubiety: many believed that it was thrown by attrition of the paper surface into the room atmosphere as a fine powder; others, that it was volatilised by heat in the upper levels of the room. It has now, however, been definitely determined that its source is a gaseous compound of arsenic, viz.: *diethylarsine.* While Gmelin was the first to draw attention to this form of arsenical poisoning, it was left to Bujwid,[1] Morpurgo,[2] Gosio,[3] Abel and Buttenberg,[4] Biginelli,[5] and others to indicate the true cause. From the researches of these investigators, there cannot be the least doubt that the factors in the production of diethylarsine are microscopic moulds or fungi, of which there are at least ten which have the power not only to live and grow freely in arseniferous media, but to decompose arsenious acid or its salts into the gaseous form named. Of these ten *Penicillium brevicaule* is probably the most powerful. Indeed it has been demonstrated that this mould, on being cultivated in a medium which contains a soluble or insoluble salt of arsenic, will decompose into the gaseous form, and thus enable so small quantities as 0·01 milligramme and even 0·001 milligramme of arsenic to be detected.

Arsenic may also be found as an accidental adulterant of many substances. Its alliance with copper in Nature, and the manufacture on the commercial scale of sulphuric acid from arsenical pyrites, and the further manufacture of hydrochloric acid from such arseniferous sulphuric acid and common salt, all indicate lines of adulteration. Indeed it may be said with strict relation to fact, that arsenic-free commercial sulphuric acid, hydrochloric acid, copper, or zinc does not exist in the market; hence the great necessity for establishing the purity of these reagents when they are to be used for the detection of arsenic. Such arseniferous acids, therefore, when used in the manufacture of other substances—as in the manufacture of glucose, from which beer was manufactured for the Manchester

[1] *L'Union Phar.*, vol. xlvi. p. 293.
[2] *Oesterr. Chem. Zeit.*, i. 167.
[3] *L'Orosi*, 1900, vol. xxiii. pp. 361–377.
[4] *Zeit. Hyg.*, vol. xxxii. pp. 449–490.
[5] *Atti. Real. Accad. Lincei*, 1900, vol. ix., ii. pp. 210–214, and pp. 242–249.

market, and which gave rise to such widespread arsenical poisoning—may be far-reaching in their effects. This, however, was not unknown before the Manchester outbreak. Ritter of Rouen[1] pointed out that glucose, by reason of its being manufactured with such impure acid, may convey arsenic into beer, confectionery, syrups, and other food-stuffs. Death, too, may happen from arsenical poisoning in unlooked-for ways. At an inquest held at Camborne, it was shown that a girl of eight died from the effects of arsenical inhalation, due to her having fallen into an arsenic flue while walking along a pathway with some other children.

SYMPTOMS.—These may be divided into

I. Acute or Sudden; and

II. Chronic or Prolonged.

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painful respiration brought about by the painful condition of stomach and diaphragm; the skin becomes cold and clammy, or, at first, this condition may be alternated with flushes of heat all over the body. Death is usually preceded by great general restlessness, by some form of paralysis, or by convulsions, or coma.

II. *Chronic or Prolonged Poisoning.*—In whatever way the poison is exhibited in the form of small repetitive doses, the general symptoms are remarkably constant in their character. These have reference to (1) the general nutrition of the body; (2) facial appearance; (3) gastro-intestinal irritation; (4) skin-eruptions; and (5) implication of nervous system. One of the earliest signs, probably, is the gradual loss of flesh, which indicates malnutrition; and accompanying this, there will probably be falling out of the hair, ragged growth of the finger-nails, and pigmentation of the skin. The facial features are somewhat striking:—The eyes are suffused and watery, the conjunctivæ being reddened and congested, and there is increased nasal secretion — in short, symptoms of coryza. The tongue presents either a reddened, raw condition, or it is covered with a thick, white coating. Eczematous eruptions may be present on the body, which are usually accompanied by increased pigmentation of the skin, or the skin may assume an earthy, or jaundiced appearance. The patient will complain of symptoms of gastro-intestinal catarrh—a feeling of sickness after food, with or without succeeding vomiting, of loss of appetite, or even loathing for food, catarrhal diarrhœa, or diarrhœa alternated with constipation. The nervous symptoms, although not characteristic or pathognomic, are striking. The patient complains of numbness of skin of hands and feet, hence he is unable to handle articles easily, firmly, or freely, and he walks with unsteady and uncertain gait, if able to walk at all. There may also be mental hebetude, or delusions. These symptoms of peripheral neuritis may be accompanied by some measure of paresis or paralysis of the limbs.

FIG. 98.—Arsenical Pigmentation of Abdomen. The patient, of whose body this is a photograph, was a confirmed beer-drinker, and was one of the victims of arsenical beer. The pigmentation, which, over the breasts, around the axillæ, and over the back, was almost greenish-yellow in colour, and too pale to show in the photograph, was darker over the abdomen, where it was yellowish-brown in colour, and showed papery exfoliation of superficial pigmented skin-layers. There was no pigmentation of face or inside of mouth. This case was recorded[1] by Professor Hall, to whom we are indebted for use of illustration.

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In 1828, a mysterious outbreak occurred in Paris, involving about 40,000 persons, which was believed by some, from the symptoms exhibited, to have its origin in arsenical poisoning. In 1885, at Havre, fifteen persons were seized with symptoms which at first resembled enteric fever, and then influenza, until symptoms of paralysis appeared. Brouardel and Pouchet investigated the cause of the outbreak, discovered arsenic in the osseous tissues of those who had died, although there were no trace of it in the viscera.[1] In 1889, an outbreak involving 405 persons occurred at Hyères, which was found to have originated in the mistake of a wine merchant who poured arsenical solution into his wine casks. Brouardel[2] also records a similar seizure at St. Denis, due to the presence of this poison in bread, from which 268 persons suffered. The presence of arsenic in bread may be accounted for by the use of hydrochloric acid and sodium carbonate to generate carbonic acid in the aeration of the dough, since commercial hydrochloric acid commonly contains arsenic in smaller or larger percentage amounts.

Elimination of Arsenic from the Body.—It is clear that arsenic is not a cumulative poison, but that the process of elimination from the body by different organs begins at once, so long as the physiological action of these organs is not crippled by consequent pathological changes. The kidneys are the principal emunctory organs, although the stomach seems to share this duty, since even in poisoning by AsH_3, vomiting is an early and prominent symptom. From the knowledge of these facts, diagnosis of the presence of arsenic in the body of a person who presents the foregoing line of symptoms may be made by the detection of arsenic either in the urine, or in the vomited matter.

Post-Mortem Appearances.—The severity of these appearances depends very largely upon the quantity taken, and the period which elapses between the time of taking and the occurrence of death. The stomach is, primarily, the seat of post-mortem appearances, even although the poison has been introduced into the body by other ways than ingestion. When the poison has been swallowed the mucous membrane is found to be highly inflamed in many small patches, which correspond to deposits of the poison, round which the inflammatory changes centre; occasionally however, the mucous membrane may be detached in patches from the underlying muscular coat. The surface of the membrane is generally covered with tenacious mucus, streaked or deeply tinged with blood. In the centre of the inflamed patches may be found small gritty deposits of the arsenious acid. The mucous membrane has, upon occasion, been found ulcerated, and, in rarer cases, gangrenous. The contents of the stomach vary in colour from a dull-brown to a brownish-red, like "coffee-grounds" in appearance, due to altered blood. The cardiac end of the stomach is usually more inflamed than the pyloric, doubtless due, in some measure, to the vomiting. The mucous membrane keeps a tenacious hold of the gritty particles of the acid once they have entered the stomach. In the case of L'Angelier for causing whose death Madeleine Smith was tried, notwithstanding there had been persistent vomiting for eight hours, 88 grains of arsenious acid were found in the stomach after death. In other cases which have been recorded, and after varying lengthy periods of vomiting, quantities amounting to sixty and thirty grains of the acid have been found in this organ

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market, and which gave rise to such widespread arsenical poisoning—may be far-reaching in their effects. This, however, was not unknown before the Manchester outbreak. Ritter of Rouen[1] pointed out that glucose, by reason of its being manufactured with such impure acid, may convey arsenic into beer, confectionery, syrups, and other food-stuffs. Death, too, may happen from arsenical poisoning in unlooked-for ways. At an inquest held at Camborne, it was shown that a girl of eight died from the effects of arsenical inhalation, due to her having fallen into an arsenic flue while walking along a pathway with some other children.

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after death. Perforation of the stomach is rare, but has been observed in a few cases. The small intestine shares in the inflammatory disturbance, and while in some cases the effect is general, in most it is mainly confined to the duodenum. In the large intestine, the rectal portion is generally most affected; this is probably to be accounted for by the great tenesmus which prevails along with the diarrhœa. The above appearances persist for variably long periods after death, doubtless due to the antiseptic nature of the poison;[1] they have been found present, for example, twelve months after death in one case, and nineteen months in another. While the foregoing may be taken to be descriptive of the appearances in the average fatal case where the poison has been ingested, their incidence is but little changed no matter by what other channel the arsenic enters the body. They are found, for example, in cases of respiratory poisoning by AsH_3, and even where the arsenic has been introduced *per vaginam.* Kockel showed the genital tract, liver, and kidneys of a woman of 27, who died from arsenical poisoning, the poison having been introduced into the vagina.[2] In addition, however, to the inflammatory appearances described, fatty degenerative changes of involuntary muscle-fibre and of tissues of kidney and liver are found, with disintegration of the red blood-corpuscles, and a jaundiced condition of the skin.

Reference has already been made (p. 114) to the preservative influence of arsenic upon the tissues of those poisoned by this substance. This has been frequently observed and noted. But the facts recorded by Whitford[3] of the appearances of the bodies of the victims of Flannagan and Higgins, who were tried at Liverpool in 1884, are of special interest. By reason of arsenical poisoning having been established in one of the three victims, the bodies of two other persons—Mary Higgins and John Flannagan, aged 10 and 24 years respectively—were exhumed and examined. Although the body of Mary Higgins had been interred for about 13½ months, and that of John Flannagan for 37½ months, both were found to be in a remarkable state of preservation. In the case of Flannagan, indeed, the face and body generally could be easily identified.

The abdominal viscera of Mary Higgins were found on analysis to contain 1 grain, and those of John Flannagan, 3¼ grains of arsenious acid. Another noteworthy appearance found in the stomach and intestines of the bodies of those poisoned by arsenic after interment, and which was found in the above cases, is a golden-yellow pigment or coating of the mucous surface of those parts. This was believed by some observers to be composed of arsenic sulphide. But Campbell Brown and Davies of Liverpool subjected the pigment found in the foregoing cases to chemical analysis,[4] and they found that it did not contain any appreciable amount of arsenic, but that it mainly consisted of bile-pigment. (For other cases of arsenical poisoning, consult *The Lancet*, vol. i. 1854, p. 224 (Atlee Family); and ibid., vol. i. 1862, p. 325.)

[1] (1) *Dublin Journ. Med. Science*, 1888 (Pearson) in *re* R. *v.* Cross; (2) *Annales d'Hyg.*, 1889, Brouardel and Pouchet.
[2] *Monats. f. Geb. u. Gyn.*, May 1899.
[3] *B. M. J.*, vol. i., 1884, p. 504.
[4] Ibid., p. 506.

Fatal Dose.—The smallest recorded fatal dose is two grains. Recovery has occurred, however, after larger doses.

Fatal Period.—While death has occurred in individual cases at the end of twenty minutes and ten hours respectively, the average fatal period may be considered to be from twelve to forty-eight hours. L'Angelier died within fifteen hours. Death, however, may not supervene so early even after very large doses of the poison; in one case, for example, where 220 grains were swallowed, death did not ensue until the seventh day; in a second, until the sixteenth day; and in a third, where the poison was absorbed through the skin, until the twentieth day.

Treatment.—The first thing to do is to evacuate the stomach of its contents by the siphon-tube, using in the in-going warm water freshly-prepared hydrated ferric oxide, made by acting upon the tincture of perchloride of iron with ammonia or potassium carbonate, and after several washings, the last ferrated water should be allowed to remain in the stomach. Sedatives may thereafter require to be used, and careful attention must be paid to feeding the patient.

Chemical Analysis.—In examining the stomach and its contents after death, great care should be paid to the examination of the mucous membrane for the presence of minute gritty particles embedded therein, which will most likely be the case where powdered arsenious acid has been administered. Stevenson[1] affirms from his experience that a person may die quickly after taking a large amount of solid arsenious acid, and yet not a particle of the solid arsenical compound be found in the organs. This is best done by exploring systematically the whole mucous surface with the finger-tip. Special attention ought to be given, at the same time, to the presence or absence of particles of indigo, or soot, as affording presumptive evidence of the kind of arsenic administered. If such gritty particles be found, they should be detached and preserved, in the meantime, in a clean watch-glass. The same procedure should next be adopted with regard to the contents of the stomach, and any gritty particles found should be placed alongside the others. In order to test whether these are composed of arsenious acid, one or two of these particles should be picked out, washed gently in distilled water, dried between folds of clean blotting-paper, and transferred to a clean flat-shaped reduction-tube. The tube being then heated carefully over a small Bunsen flame, the formation of a sublimate should be looked for, and, if found, should then be examined by a good hand-lens or low-power microscope. If the character of the sublimate be crystalline and the crystals of the octohedral type, the strong presumption is in favour of arsenic (*vide* Fig. 97). The piece of tube bearing the sublimate may then be cut off, ground in a small mortar, acidulated with pure hydrochloric acid, and tested with the liquid tests to be afterwards described. Should the reactions prove that the gritty particles are composed of arsenic, the rest may be washed carefully, dried, and weighed, and the weight noted. They should be preserved after weighing. If, however, no such particles are found, we may employ in testing the liquid contents of the stomach,

[1] *B. M. J.*, vol. i. 1884, p. 485.

after acidulating with pure hydrochloric acid to one-sixth the volume, *Reinsch's test* as a preliminary.

Reinsch's Test.—To the mixture, two or three small pieces of pure copper foil about ¼-inch square are added, and the whole boiled for about fifteen minutes.

In all cases where Reinsch's test is used for the detection of arsenic, it is imperative that the copper foil should be proved to be pure. Its purity may be established by the following preliminary test proposed by Abel. To some pure hydrochloric acid add five equivalents in bulk of water, and a few drops of a weak solution of ferric chloride or ferric sulphate. After boiling the mixture for a few minutes, add the small pieces of bright polished copper foil while the fluid is still boiling, and continue the boiling for a few minutes longer. If the metal is arsenic-free, its original bright colour will remain unchanged; but if it be contaminated, it will acquire a darkened or tarnished appearance.

Pure copper foil may now be obtained, however, by electrolysis. To save hunting in the mixture for the small pieces of copper, each may be attached to a convenient length of fine platinum wire, by aid of which they are lifted out at the completion of the process. Should a steel-grey deposit have formed on the copper, the pieces may be detached, dipped in water, ether, and alcohol respectively, dried, placed in a reduction tube, and carefully heated. Should a sublimate form, the steps already described for identifying its arsenical character, should be taken. Should this test reveal the presence of arsenic, the mixture may then be placed in a dialyser, so as to separate out the arsenic from the organic matter; after which, it may be treated for quantitative estimation.

It must be borne in mind that, in addition to arsenic, dissolved antimony, bismuth, gold, mercury, platinum, silver, and tin are deposited upon copper when boiled in an acid solution, but only arsenic, antimony, and mercury sublime from the copper when it is heated in the reduction tube.

Reinsch's test fails in its action in the presence of chlorates and nitrates, and it also fails to take up all the arsenic which may be present in the material suspected.

Liquid Chemical Tests.—The liquid tests for arsenious acid in solution may now be described. They are as follows:—

1. Ammonio-Nitrate of Silver gives a pale yellow precipitate of the Arsenite of Silver, which on exposure to sunlight changes to a green colour. The precipitate is soluble in excess of ammonia, in nitric acid, and in tartaric, citric, and acetic acids. Nitrate of Silver alone gives no precipitate.

2. Ammonio-Sulphate of Copper gives a beautiful light-green precipitate of Copper Arsenite, known as Scheele's green, which is also soluble in excess of Ammonia. Cupric Sulphate alone does not produce a precipitate.

3. Sulphuretted Hydrogen gives a bright yellow precipitate of Arsenious Sulphide, which is soluble in excess of Ammonia. It is important to remember that unless the solution to be tested is acid, no reaction will occur. The sulphide is recognised as follows: (*a*) By its insolubility in dilute hydrochloric or vegetable acids, alcohol, and ether; (*b*) by its being decomposed by *strong* hydrochloric or nitric acid; (*c*) by its solubility in alkalies; (*d*) by yielding metallic arsenic when treated with soda-flux.

Marsh's Test.—This test, or process, depends upon the fact that soluble arsenical compounds are decomposed by nascent hydrogen. This is commonly generated by the action of dilute sulphuric or hydro-

chloric acid on metallic zinc, and the arsenic unites with the hydrogen to form arseniuretted hydrogen, AsH_3. By reason of the risk of unreliable results from the use of impure reagents, several modifications of the process of generating the hydrogen have been suggested, as, for example, by Bloxam and others. Although Marsh himself used zinc and sulphuric acid, the use of magnesium has been suggested because of the difficulty of procuring zinc free from arsenic. Another reagent suggested in place of zinc is sodium amalgam, which can be made arsenic-free in the following way: by melting one part of pure metallic-sodium under solid paraffin, and by gradually adding, by constant stirring, ten parts of purified mercury, a solid crystalline mass of amalgam or alloy is formed, which, when the paraffin is decanted off and the mass is washed with pure, dry benzene, is ready for use. A few small pieces of the alloy are sufficient for one estimation. But if we make sure that the reagents used are pure, those originally proposed by Marsh will equally efficiently serve the purpose. The apparatus for the test consists of an Erlenmeyer flask or Wolff bottle. In the former, which has one mouth, the mouth of the flask is fitted with an accurately-ground glass stopper in which two holes have been drilled. Through these holes are passed accurately-fitting glass tubes, one of which is thistle-shaped at the top and is caused to pass to nearly the bottom of the flask, the other at its one extremity just passes through the stopper, and at its other end above the stopper, is bent twice upon itself, and is connected with a calcium chloride tube, which, in turn, is united with a lengthy piece of glass tubing narrowed about two or three inches from its free extremity. In using this test practically, it is of great importance that the medium in which the arsenic is suspected to be present should be in a liquid form and as free from organic matter as possible, since organic matter is apt to interfere with the efficiency of the test. Assuming that either by dialysis, or in some other way, the medium is obtained in the liquid form, several pieces of pure, granulated, metallic zinc are added to some distilled water in the flask of the apparatus; thereafter some of the suspected fluid is added; and, last of all, some pure dilute sulphuric acid is poured down the thistle funnel, the result being the generation of hydrogen, and, if arsenic be present, of arseniuretted hydrogen. If the zinc be pure, it is better to add a drop or two of platinic chloride solution, so as to aid the rate of evolution of hydrogen, since pure zinc is but slowly attacked by the acid. After waiting a few moments to permit of the air of the flask being replaced by the hydrogen-arsenide gas, a light may be applied to the issuing gas at the free end of the tube. Hydrogen arsenide may be recognised by the following properties, viz.: (*a*) it burns with a pale bluish, bluish-white, or lilac flame; (*b*) if a piece of white porcelain be held in the point of the flame, a deposit forms upon the porcelain, which may be roughly differentiated into three separate zones or rings, and those, from circumference to centre, are composed as follows: (1) a whitish ring composed mainly of arsenious acid; (2) a darkish-coloured or brownish ring, composed of a mixture of arsenious acid, arsenious suboxide, and metallic arsenic; and (3) a dark, shining ring of purely metallic arsenic. That these stains are composed of arsenic may be proved by the following tests, viz.: (*a*) by their

solubility in a solution of sodium hypochlorite, or of chlorinated lime or bleaching-powder; (*b*) by their imperfect solution in amm onium sulphide, which solution, however, on evaporation to dryness, leaves a yellow film of arsenious sulphide; (*c*) by being dissolved on addition of nitric acid, and the resulting solution on being carefully evaporated to dryness, and on addition of a drop or two of a strong solution of silver nitrate, giving a brick-red stain or precipitate of silver arsenate. During the time these tests are being tried, it is advisable to turn the delivery-end of the tube into a solution of silver nitrate, so as to prevent escape of the AsH_3 into the room atmosphere, and also to prevent its possible poisonous action on the experimenter—for this gas is very lethal in its action; or a lighted spirit-lamp may be applied to the issuing-tube, an inch or more on the proximal side of the constriction. The effect of the application of the lamp is to decompose the AsH_3 into hydrogen and metallic arsenic, and a dark-brown mirror of metallic arsenic will be deposited within the tube on the distal side of the point to which the heat has been applied. When the tube is sufficiently cooled to enable it to be detached, the mirror may be again heated by the spirit flame, when the arsenic will sublime on a cool part of the tube in the characteristic crystalline form of arsenious acid. The sublimate may then be dissolved in distilled water acidulated with hydrochloric acid, and the liquid tests, already described, can be applied. It is often well to preserve intact a portion of the tube with the deposit thereon, by sealing the ends with the blow-pipe, for presentation as evidence. Marsh's test is capable of detecting the $\frac{1}{250}$ of a grain of arsenic.

Gutzeit's Test.—When a preliminary test is wanted where only a small amount of material is on hand for analysis, perhaps one of the best tests is that of Gutzeit.

Gutzeit's test, as originally suggested and carried out by its proposer, consisted in the generation of AsH_3 from an arseniferous material by means of zinc and HCl, and passing the gas so liberated upon or against a piece of bibulous paper moistened with silver nitrate. While this salt of silver possesses the advantage of being very sensitive to AsH_3, it unfortunately has the disadvantages that it is liable to be darkened on exposure to light, and is, also, very readily affected by H_2S. The accidental presence, therefore, of H_2S when testing for AsH_3, destroyed the accuracy and reliability of the test. It was for this reason that mercuric chloride was substituted in place of the silver salt, and although it is not so rapidly reactive to AsH_3 as the other, when due precautions are taken, it is a surer indication of the existence of arsenic when a reaction does take place. It must not be considered that the mercury salt is not affected by H_2S; all that can be claimed, indeed, in favour of its use over the other, is that it is less sensitive, and that a stain is only produced when sufficient H_2S is present to be easily detected by lead acetate paper. It will be apparent, therefore, that in this lies the weakness of the test, as commonly carried out, and that the presence of sulphides or sulphites in the material to be examined militates against its accuracy. When these were suspected to be present in the material to be examined, it was necessary to add iodine or bromine to oxidise the sulphur compounds. The effect of AsH_3 upon a dried spot of mercuric chloride is a yellow coloration of the hitherto colourless spot, the depth of the resulting tint depending upon the amount of arsenic present; but it varies from a lemon-yellow, through a bright yellow, to an orange-brown colour.

This test, which is far more sensitive to the presence of minute amounts of arsenic than that of either Reinsch or of Marsh, would,

obviously, be practically perfect could adventitious gases be arrested before they could act upon the sensitive mercury spot. Such an apparatus and method of use have been devised by Dowzard.[1] A sketch of the apparatus is given in the article quoted, but we reproduce it here.

The principle of the apparatus is to arrest or trap, and to wash in neutralising solutions, those gases which would interfere with the integrity or accuracy of the test. The apparatus itself essentially consists of an Erlenmeyer flask, and of a series of superposed glass cells which are fitted into the flask after the fashion of a series of fitting hollow stoppers, one above the other. Dowzard's description of the mode of using the apparatus is as follows :—

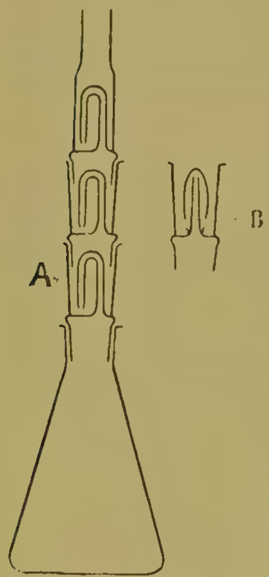

FIG. 99.—Dowzard's Apparatus for Gutzeit's Test for Arsenic. A and B indicate glass cells or traps which contain solutions of Lead Acetate and Copper Chloride for the purpose of fixing H_2S and PH_3 which otherwise would react upon the Mercuric Chloride spot on the filter-cap. The cells are fitted into one another, as shown in the figure.

"A weighed or measured portion of the sample is mixed with 5 c.c. of pure HCl (if the sample is alkaline, it must be neutralised first), four drops of a 15 per cent. solution of cuprous chloride in hydrochloric acid are then added, and the mixture made up to 30 c.c. with water; if it is not convenient to work with such a small bulk as 30 c.c., this quantity may be doubled or trebled, but the same proportion of acid should be used. A rod of pure zinc, 3 cm. long and 5 mm. in diameter, is first placed in the flask, the above mixture is then introduced, and the first cell placed in position ; lead acetate solution (5 per cent.) is now poured into the cell until it is about half full, the second and third cells are filled in a similar manner, a small tuft of cotton wool is introduced into the neck of the top cell, and its mouth capped with mercuric chloride paper, which may be held in position by an elastic band, or a glass collar made from a piece of glass tubing. After forty minutes or more, the cap is removed and examined in full daylight. A minute trace of arsenic is indicated by a lemon-yellow spot, which varies in tint according to the amount present; and a heavy trace by an orange-brown spot. The mercuric chloride paper is prepared as follows: one drop of a 5 per cent. solution of mercuric chloride is allowed to fall on the centre of a piece (4 cm. square) of thin, Swedish filtering paper such as Muncktell's No. 1 F.; the paper is dried before using."

Used in the above manner, sodium sulphite and sodium hypophosphite were tested in the apparatus: it was found that the lead solution completely absorbed the H_2S from the former, but did not prevent the PH_3 from the latter from passing to stain the mercuric paper. But by placing in the other cells a 15 per cent. solution of cuprous chloride in hydrochloric acid, the PH_3 was also prevented from passing to cause a stain. With the cells charged as described, 0·000005 gramme of arsenious acid was added to the solution in the flask, when the mercuric cap was stained a faint yellow colour. Dowzard concluded from his experiments, therefore, that the use of lead acetate and cuprous chloride solutions does not interfere with the passage of AsH_3, but effectually arrests the passage of H_2S and PH_3 respectively. Moreover, he tested the value of the apparatus in respect of SbH_3, and he found, by using amounts of potassium-antimony tartrate up to 0·10 gramme, and washing the gas produced in three cells charged with cuprous chloride solution, that in no case was a stain produced, but when the amount was increased to 0·20 gramme, that a faint blackish-brown stain was formed. From the foregoing, it was concluded that arsenic can be detected even in

[1] *Journ. Chem. Soc.*, vol. lxxix. and lxxx., 463, p. 715.

presence of about 2500 times its weight of antimony. Dowzard recommended, when antimony is present, that the proportion of acid to be used should be 1 in 8, and that only *one* drop of cuprous chloride solution should be used, so that the rapidity of evolution of hydrogen may be moderated, and thus enable the cuprous solution in the cells to exercise its full absorbing effect. The presence of selenium and tellurium compounds does not interfere with the usefulness of this method. In order to make the test of value for quantitative estimations, Dowzard suggests that careful attention should be paid to the following points, viz.: (1) That parallelism with respect to amounts of reagents and temperature of the experiment be carried out in every particular; (2) that the reaction should occupy the same time; (3) that the stain produced from a given sample be carefully compared with stains produced from known standard amounts of arsenious acid; and (4) that exactly duplicate apparatus be used.

The cuprous chloride solution is prepared in the following way: dissolve 16 grammes of pure cupric oxide in 110 c.c. of pure hydrochloric acid; to this solution add 13 grammes of pure thin "electric" copper-foil cut into small pieces, and boil the mixture for 25 minutes; then pour the resulting solution of cuprous chloride into 1000 c.c. distilled water, and wash the white precipitate by decantation; dissolve the washed precipitate in arsenic-free hydrochloric acid; evaporate to dryness 5 c.c. of the solution; weigh the residue; and from the weight found, dilute the bulk of the solution with HCl until 100 c.c. contain about 15 grammes of cuprous chloride.

For quantitative estimation of arsenious acid in organic mixtures, such as contents of stomach, or in the bodily organs, in view of the fact that dialysis is but a slow way of effecting separation of the poison, a process of distillation has been established on the principle that the Chloride of Arsenic ($AsCl_3$) is volatile. Whatever be the nature of the organic substance suspected to contain the arsenic, it is finely pounded into pulp, and dried in a water-oven at 212° F. When quite dried, it is placed in a distillation-flask or retort, which can readily be attached to a condenser, the adapter of which dips into a receiver containing sodium or potassium hydrate solution. Thereupon to the flask or retort is added sufficient pure hydrochloric acid to cover thoroughly the dry organic matter; the retort is connected with the condenser—which, like the receiver, must be kept cool by a water-jacket—and heat is applied by means of a sand-bath. The distillation is proceeded with until about three-fourths of the acid have passed over The retort is now allowed to cool for a little time before it is opened; more hydrochloric acid is then added; and distillation is repeated in the same way. The two distillates are then mixed in an Erlenmeyer flask, warmed to a temperature of 150° F., and arsenic-free H_2S is passed through the liquid for some hours, the temperature of the liquid being maintained as uniform as possible. At the end of this time, the flask is set in a warmed place sufficiently long until the odour of H_2S has practically disappeared. The precipitate is now collected on a tared filter, washed with ether, then alcohol, and, last of all, with carbon disulphide to dissolve out any sulphur which the precipitate might contain. Thereafter it is dried to constant weight at 212° F., and the weight calculated into terms of Arsenious Acid. The amount of As_2S_3 found, when multiplied by the factor ·6098, will equal the quantity of metallic arsenic, and by ·8049, that of As_2O_3 present in the aliquot weighed quantity used.

It may happen, however, that the quantity found in the body is not sufficient to be ponderable. In such a case, the only means of

arriving with approximate accuracy at the quantity is by comparing with stains or mirrors formed in Gutzeit's or Marsh's test from definite, known small amounts of the poison, those produced in a like manner in the case in hand. It is only by such a method that very minute amounts can be estimated as quantity.

In every case where analyses are made for medico-legal purposes, portions of the materials in which the poison has been found should be retained, for the use of the defence if required.

Medico-Legal Cases in which Arsenic was Administered Criminally.

McCracken—tried at Derby Autumn Assizes, 1832.
Mary Ann Burdock—tried at Bristol, April 1835.
Poison used—Orpiment: Death of victim.
Lofthouse—tried at York Lent Assizes, 1835.
Hunter—tried at Liverpool Assizes, 1843.
Thomas—tried at Cardiff Summer Assizes, 1843.
Dazley—tried at Bedford Summer Assizes, July 1843.
Death of victim. Evidence of poison in body, six months after interment.
Lever—tried at Central Criminal Court, London, 1844.
Port—tried at Chester Winter Assizes, 1844.
Death caused by application to breast of arsenical plaster.
Gilmour—tried at High Court of Justiciary, Edinburgh, January 1844.
Jennings—tried at Berks Lent Assizes, 1845.
Poison found in body of victim, 28 days after burial.
Elizabeth Johnston—tried at Liverpool Lent Assizes, 1847.
Poison found in body of victim on exhumation after three months' interment.
Foster—tried at Bury Lent Assizes, 1847.
Cheshams—tried at Essex Lent Assizes, 1847.
Poison found in bodies of victims, 19 months after burial.
Maher and Lynam—tried at Kildare Lent Assizes, 1847.
Franklin and Randall—tried at Northampton Summer Assizes, 1848.
Poison — Schweinfurth green (aceto-arsenite of copper) used to ornamentally colour *blanc mange*, in shape of cucumber. It was found to contain 47½ per cent. of arsenite of copper.
Ann Merritt—tried at Central Criminal Court, London, 8th March 1850.
Poison—arsenious acid—administered in gruel. Amount of arsenic found in stomach of victim, 8½ grains.
Lucas and Reeder—tried at Cambridge Lent Assizes, 1850.
Death of victim.
Maria Gage—tried at Ipswich Summer Assizes, August 1851.
Poison used—packet of rat-poison, consisting of linseed and arsenious acid. Death of husband.
Mrs. Wooler—tried at Durham Winter Assizes, 1855.
McCormick—tried at Liverpool Winter Assizes, 1855. (*Med. Gaz.*, vol. xxxiii. p. 434.)
Newton—tried at Hertford Lent Assizes, 1855.
Death of victim.
Bacon—tried at Lincoln Autumn Assizes, 1857.
Madeleine Smith—tried at High Court of Justiciary, Edinburgh, 30th June, 1857.
Poison alleged to have been administered in coffee, cocoa, or other food or drink. Amount of arsenic found in body of deceased—L'Angelier —88 grains.
Sagar—tried at York Lent Assizes, 1858.
Mary Ann Cotton—tried at Durham Assizes, 1874.
Flannigan and Higgins—tried at Liverpool Assizes, in 1884.
Cross—tried at Munster Winter Assizes, December 15, 1887.
Arsenic and Strychnia found in body of wife.

Michael O'Brien—tried at same Assizes, December 14, 1889.
  Arsenic found in body of victim—$11\frac{1}{20}$ grains. (*The Lancet*, vol. ii. 1889, p. 1356.)

Mrs. Maybrick—tried at Liverpool Assizes, 1889.
  Poison used—Arsenite of Soda,—from solution of "fly-papers" in water. Death of husband. *Vide* also case reported by Dr. Letheby, *Med. Gaz.*, vol. xxxix. p. 116.

John Webster—tried at High Court of Justiciary, Edinburgh, 1891.
  Arsenic found in all the organs.

Frost—inquest held at Deptford, July 1899.
  Poison found in bodies of three victims, on exhumation of bodies after varying periods of interment. (*The Lancet*, vol. ii. 1899, p. 124.)

Antimony.

The principal salt of Antimony with which cases of poisoning have been associated is potassium-antimonium-tartrate, or tartar emetic

FIG. 100.—Photo-micrograph of Crystals of Tartrate of Antimony. × 50 diameters. (Author.)

($KSbC_4H_4O_7H_2O$). This salt is an ingredient of James's Powder. Antimony is much less used in medicine now than formerly, and when used, it is commonly in the form of *vinum antimoniale*. Tartar Emetic occurs in the form of a whitish, or whitish-yellow powder, which contains chemically between 33 and 35 per cent. of Antimony. The Chloride is corrosive in its action, as we have already seen. Tartar emetic is sometimes given to horses to improve the condition of the skin, and it has been known to be administered by wives to their husbands to wean them from drink. It is freely soluble in boiling

water—one in three,—is five times less soluble in cold water—one in twelve to fifteen parts,—and is insoluble in alcohol.

Accidental poisoning may sometimes occur in unexpected ways. Page[1] records an interesting case. At Kendal Martinmas Fair, a girl bought some confectionery at a street-stall. She ate a couple of lozenges herself, and gave the like number to two children of the family, aged three and five respectively, who ate them. In about a quarter of an hour, they were seized with violent sickness and retching, lasting an hour, while, in addition, the younger of the children became collapsed, and was unconscious for forty minutes, although she eventually recovered. The lozenges, on being examined, were found to weigh 62 grains, and each approximately contained ·22 grain of the teroxide of Antimony (Sb_2O_3). It was supposed that the antimony had been accidentally put into the mixture of which the lozenges were made. At an inquest on a child who had died unexpectedly while suffering from whooping-cough, it was shown in evidence that five doses of "Holt's specific" had been administered. On post-mortem examination of the body, patches of inflammatory action were found in stomach and intestines; and on chemical analysis of the "specific," it was found that each dose contained half a grain of tartar emetic.[2] There are preparations sold for the "cure" of dipsomania, besides, which contain antimony.

Acute Poisoning—Symptoms.—If we suppose that one or two drachms of tartar emetic have been taken, the following symptoms may be expected to be present: an astringent metallic taste in mouth; great heat and sense of constriction in the throat; dysphagia, to some extent; great pain in stomach, followed by vomiting of an incessant character; accompanying, or succeeding diarrhœa; great feeling of faintness and profound depression; there may, or may not be intense thirst; the pulse is small, rapid, and very weak; the skin is covered with a cold. clammy perspiration; there may be cramps in abdomen and limbs, which before death may almost assume a tetanic character; intense giddiness, followed by insensibility, usually precedes death.

Chronic Poisoning—Symptoms.—These consist of great nausea, followed by vomiting of contents of stomach and bile-stained mucus; watery diarrhœa, or diarrhœa alternated with constipation; the pulse becomes small, weak, and contracted; there is great loss of bodily strength, which comes on gradually, and proceeds *pari passu* with loss of flesh and emaciation; the patient loathes the sight of food, because vomiting is associated with it; great weakness, amounting to complete prostration, and increasing emaciation, generally precede death.

Post-Mortem Appearances in Acute Poisoning.—The mucous membrane of throat, gullet, and stomach is injected, inflamed, and, in parts, is superficially ulcerated. The mucous lining of stomach, especially, is likely to be found covered with a tenacious mucus, and here and there variable-sized patches of sub-mucous ecchymosis may be seen. These appearances seem to be concentrated on the greater curvature and at the cardiac orifice, although they have been found distributed generally over the stomach. The mucous lining of the duodenum shares the same appearances. The contents of stomach are usually scanty in

[1] *The Lancet*, vol. i. 1879, p. 699.
[2] *B. M. J.*, vol. i. 1884, p. 23.

amount, are dark-coloured in appearance and sometimes bloody, and give an acid reaction.

In chronic poisoning, these appearances are not so marked; the tongue and buccal mucous membrane are likely to be covered with fur, or dotted with aphthous patches; the other reaches of the gastro-intestinal tract are likely to be found in a similar state, but patches of ulceration may be found either in stomach or intestines, or in both. There is considerable emaciation of body.

Fatal Dose.—One drachm, less or more; the amount, however, is indefinite, depending much upon the constitution of the individual. The case in which a fatal issue followed one and a half grains [1] must be held to be so very exceptional that it cannot be reckoned as fixing the minimum fatal dose. Ten grains have killed a boy of five, and a like quantity a girl of three. At the same time, recovery has followed doses of 60,[2] 170,[3] and over 400 grains respectively.[4]

Fatal Period.—Sixty grains produced death in an adult in ten hours; [5] ten grains, in the boy above mentioned, in eight hours, and in the girl, in twelve hours.

Treatment.—The prime indication is to empty the stomach of the poison, by the siphon-tube. If vomiting be not free, and where the tube is not available. aid the emesis by simple emetics, and give strong boiled tea, or tannic acid. Where the siphon-tube is used, warm water alone is sufficient for lavage. Sedatives ought to be used when the improvement in the pulse and general condition indicate that the patient is out of immediate danger. Careful liquid diet must be pursued for some time after.

Chemical Analysis.—Should any of the suspected powder be obtained, its characteristic action on being heated on a piece of platinum foil will differentiate it from arsenic, since on being heated, instead of being volatilised like arsenic and leaving no residue, it blackens and leaves a dark residue of charcoal and metallic antimony.

In organic fluids, or solids which have been pounded to pulp, it may be detected by Reinsch's and Marsh's tests.

In the former, a deposit is formed upon the copper foil, the colour of which is determined by the amount of antimony present and the period of boiling; if small in amount, the colour is a violet red or purple; if larger, black and pulverulent. Upon drying the copper foil and heating it in a reduction-tube, the antimony sublimes, and the sublimate on microscopic examination is seen to consist of small amorphous particles, composed of antimonous oxide. If this be dissolved in water acidulated with HCl, and H_2S be added, an orange precipitate of the sulphide will be thrown down.

Marsh's Test. The SbH_3 burns with a greenish-white flame, and gives a black deposit of metallic antimony on a porcelain plate. It is insoluble in a solution of chlorinated lime, but is freely soluble in NH_4HS, which on evaporation to dryness, leaves an orange-coloured

[1] *Bulletin de Therapeutique*, vol. li.
[2] Dobie, *The Lancet*, vol. i. 1887, p. 773.
[3] *New York Med. Rec.*, vol. xxiv., 1883 (Carpenter).
[4] *West. Jour. of Med. and Surg.*, 1848, p. 23.
[5] *Med. Gaz.*, 1850, May, p. 801.

film of the sulphide; it is also soluble in warmed HNO_3, and the solution being evaporated to dryness, and a drop of $AgNO_3$ being added, no colour reaction is produced. If the spirit-flame be applied to the exit-tube, a deposit which consists of metallic antimony takes place at the point of application and on its proximal side. On removal of the tubing with the deposit and the fresh application of heat, sublimation takes place and a white sublimate of the oxide forms on a cool part of the tube. If the SbH_3 gas be passed into a solution of $AgNO_3$, the antimony is thrown down as antimonide of silver (Ag_3Sb), as a black precipitate.

Marsh's test, however, is not so applicable for the detection of antimony as of arsenic, since the antimony is liable to be deposited on the zinc in the generating-flask.

There is another test of the galvanic type which differentiates Arsenic from Antimony. If a portion of the acidulated suspected liquid be placed in a shallow platinum capsule, and a piece of pure zinc- or tin-foil be placed in contact with the vessel through the medium of the fluid, hydrogen is generated and the antimony is deposited on the platinum vessel. If the supernatant fluid be poured off at the end of the reaction—which may take some hours if the quantity be small—and NH_4HS is added, the deposit will dissolve, and the sulphide of the metal will be formed.

Quantitative Analysis.—If examination is to be made of a solid organ, the organ should be mashed into pulp, and a weighed aliquot portion taken, which should then be beaten into a thin paste with water acidulated with HCl (1 HCl to 5 of water), heated to a moderate heat for some time, stirring constantly, and small portions of finely-powdered chlorate of potash added from time to time to break up the organic matter. The mixture should then be allowed to cool, strained through a fine muslin cloth, and the residue well washed with distilled water; and the whole finally filtered, and concentrated, if necessary. After which, a stream of washed H_2S should be passed through the fluid for several hours, then time allowed for the precipitate to settle. The precipitate, after being filtered and washed, is collected in a porcelain-boat, which is placed in a hard glass tube through which dried CO_2 is caused to pass, and is heated until all moisture and accidental sulphur from the H_2S are expelled. Thereafter the precipitate is weighed. One part of the precipitate is equivalent to ·7177 parts in terms of metallic antimony.

Medico-Legal Trials for Poisoning by Antimony.

1. Dr. Pritchard—tried at the High Court of Justiciary at Edinburgh, July, 1865.
   Chronic poisoning of wife by antimony, and of mother-in-law by antimony and aconite, administered in food.
   Antimony was found in the exhumed bodies of both.
2. Dr. Smethurst—tried at Central Criminal Court, July and August, 1859. *Vide* Stephen's "History of the Criminal Law of England," vol. iii. p. 438; and Sessions Papers, Central Criminal Court, 1859.
   Death of wife.
3. Thomas Winslow—tried at Northern Circuit, Liverpool, Aug. 20, 1860.
   Victim suffered from disease of Cæcum.
   Antimony found in vomit, urine, fæces, and in internal organs of deceased.

4. Bravo case—Inquests on body of Mr. Bravo, 1876. Verdict of Jury—Death from Tartar Emetic; Wilful murder by person or persons unknown.
5. McMullen—tried at Liverpool Summer Assizes, 1856.
   Chronic Poisoning. Small doses of tartrate administered at intervals of four months.
   Poison found in liver, spleen, kidney, urine, and fæces.
6. Freeman—tried at Drogheda Spring Assizes, 1857.
7. Hardman—tried at Lancaster Summer Assizes, 1857.

For an account of Nos. 5, 6, 7, see "Guy's Hosp. Reports," Oct. 1857.

Mercury.

Mercury was at one time freely used in the trade of mirror-silvering, but its use has been largely supplanted by other processes. It is still used, however, by furriers and philosophical instrument makers. In the metallic state, when taken into the system, it is comparatively innocuous. Its salts are largely used in medicine for internal and external treatment, and mercuric chloride has come into wide use as a germicide or disinfectant in the public health service. The principal poisonous salt which is encountered by the medical jurist is mercuric chloride or corrosive sublimate, although poisoning has resulted from other salts.

Corrosive sublimate may be found in heavy crystalline masses, or as colourless, transparent, rhombic prismatic crystals. It has an acrid, styptic, metallic taste, and one part of it is soluble in about fourteen parts of water at the ordinary temperature. It is soluble in alcohol in the proportion of one in three, and more freely in ordinary ether—to the extent of one-third of its weight. It is but sparingly soluble in chloroform. The other salts which are poisonous are mercuric oxide or red precipitate, ammonio-mercuric chloride or white precipitate, and mercuric nitrate.[1]

Kennedy[2] records a case of attempted suicide by a woman who took about two drachms of red precipitate, but who recovered. Her symptoms were: burning pain in stomach, vomiting, with hæmatemesis the next day, and bloody stools. Doubtless her life was saved by the early onset of vomiting.

Acute Poisoning—Symptoms.—The symptoms come on almost immediately, or soon after the poison is swallowed. A metallic, acrid taste is perceived in the mouth, with a sense of constriction or suffocation in the throat, accompanied by burning heat, which extends down the gullet to the stomach; violent pain is experienced in the region of the stomach, which is increased by pressure, followed by nausea and constant vomiting. The vomit consists of bloody, tenacious mucus, after the ordinary stomach contents have been evacuated. There is profuse diarrhœa, with severe tenesmus, the stools being composed latterly of bloody mucus. The face is pale, anxious, and at times somewhat swollen; it may be flushed at first however. The pulse becomes small, feeble, and irregular, the skin cold and clammy, respiration difficult, and syncope, convulsions, or general insensibility generally precedes death. The urinary secretion is either

[1] Stevenson, Guy's Hosp. Rep., vol. xix. p. 415.
[2] *B. M. J.*, vol. i. 1884, p. 56.

entirely suppressed or scanty in amount, and is albuminous and bloody.

Post-Mortem Appearances.—The tongue is white and sodden-looking, and the mouth generally has a whitish aspect. The mucous membrane of throat, gullet, and stomach is, as a rule, more attacked than that of mouth, and is of a whitish or bluish-grey colour, and is inflamed or ulcerated in parts. In the stomach, especially, there is more or less general evidence of inflammation, there may be considerable extravasations of blood, and the muscular coats are often so softened that it is difficult to remove the organ without rupturing them. The inner lining of the intestines more or less shares in the inflammatory condition, and the cæcum, colon, and rectum may be the seat of violent inflammatory action. Perforation of the stomach has been recorded in one case, but is rarely found.

Chronic Poisoning—Symptoms.—Notification of cases of industrial poisoning must be made under Section xxix. of the Factory and Workshop Act, 1895, and since May 1899 is compulsory on practitioners. The principal occupations in which mercury is used are philosophical instrument makers and furriers. Of about 300 workers in these occupations, ten exhibited symptoms of mercurial poisoning. In these, the main symptoms were: increasing anæmia, gastric disturbance, salivation, inflammation and tenderness of gums, and tremor affecting chiefly muscles of face, hands, and arms. Some measure of paralysis may also be present. In the occupation of furrier, in which the worker is exposed to the fumes of mercuric nitrate, the teeth become blackened and loosened, and the gums recede from the teeth. Where the poison is administered internally in repeated doses, the symptoms are usually somewhat more severe. The patient suffers from colicky abdominal pains, nausea, vomiting, and general depression. The gums are swollen and may slough in patches, salivation is present, the teeth become loosened, and the salivary glands are swollen. A blue line is seen at the junction of teeth and gums, and there is often much fœtor from the mouth. The patient becomes emaciated, may spit blood, may be seized with a cough, has general muscular tremor, becomes paralysed in the limbs, and dies of exhaustion. Before death the patient may be subject to mental disturbance accompanied by hallucinations. There may be skin symptoms.

Fatal Dose.—Three grains have killed a child,[1] and a similar dose, an adult.[2] This amount may be reckoned, therefore, as the minimum fatal dose. Recovery has, however, succeeded much larger doses; after 19 grains;[3] after 30 grains;[4] after 9½ grains;[5] and after still larger doses; and of the red oxide, 30 grains.

Fatal Period.—Probably the shortest recorded is half-an-hour;[6] the next is *two* hours;[7] the time, however, is variable, extending usually into days.

Treatment.—If vomiting be present encourage it; if absent, promote it by the handiest emetic, or wash out the stomach with the

[1] *The Lancet*, 1845, p. 297.
[2] *Med. Gaz.*, vol. xxxv. p. 778.
[3] Guy's Hosp. Rep., 1850, p. 213.
[4] *Med. Gaz.*, vol. xxxi. p. 942.
[5] *B. M. J.*, vol. i. 1900, p. 709.
[6] Taylor's "Poisons," p. 462.
[7] *Med. Gaz.*, vol. xxxi. p. 557.

siphon-tube, using care in its introduction. Magnesium carbonate may be mixed with the ingoing water. Albumen, in the form of raw white of egg, should be passed in last, and ought to be allowed to remain as long as it will in the stomach. Afterwards, treatment must be followed as symptoms indicate.

Chemical Analysis.—If a portion of the crystalline substance be heated on platinum foil, it first melts, and is then dissipated in the form of a white vapour, leaving no residue. If a portion be heated in a reduction-tube, the same phenomenon is observed, and the sub-

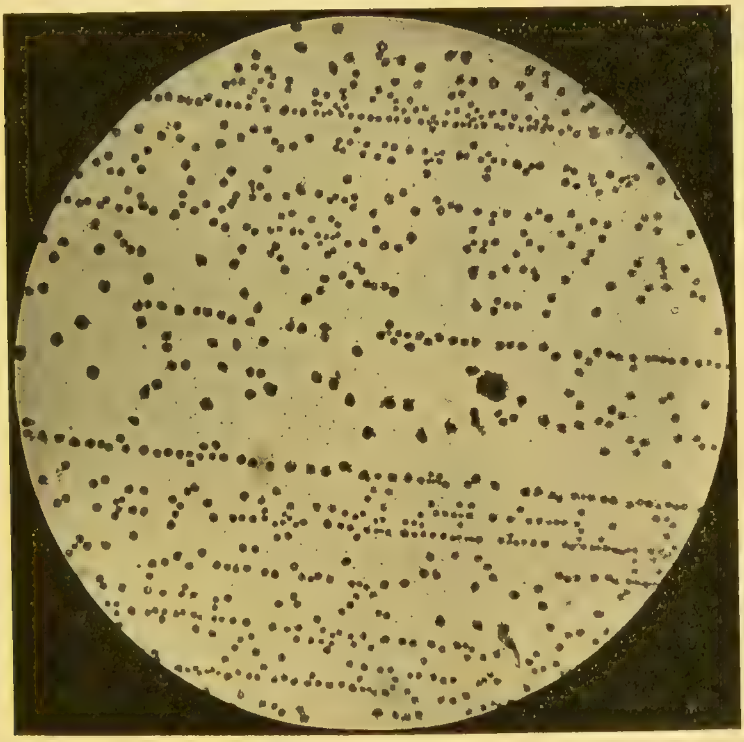

FIG. 101.—Photo-micrograph of Globules of Mercury obtained by sublimation. × 50 diameters. (Author.)

limate formed by the vapour will be seen on microscopic examination to consist of minute globules of mercury.

In organic substances, such as the contents of stomach, vomited matter, or pulped organ, it may be detected by Reinsch's test. The deposit on the copper-foil has a distinct silvery appearance. On heating the foil in a reduction-tube, sublimation takes place as described. The sublimate may be dissolved with HNO_3, and the following liquid tests applied, viz.:—

1. A drop of a solution of KI gives a bright scarlet precipitate.
2. A drop of KHO gives a reddish-yellow, or yellow precipitate.
3. H_2S gives a brown or black precipitate, which is insoluble in alkalies or dilute acids.
4. A solution of stannous chloride gives latterly a black precipitate of metallic globules of mercury.
5. If a bright steel needle or knife be immersed in the solution, the mercury will be deposited upon the needle or knife, as a silvery mirror.

Quantitative Estimation.—This may be done either by the wet or dry method. The first consists in taking a weighed aliquot part of the substance which, by the preliminary test, is known to contain mercury, adding one-fourth of its weight of HCl, and rubbing the whole into a thin paste with addition of water. The whole is now heated and kept at nearly boiling point, pinches of powdered chlorate of potash being added from time to time. The heating is continued until the mass is converted into a homogeneous liquid, and until the odour of chlorine has disappeared. It is then allowed to cool, is filtered, and any remaining residue is well washed with water. The filtrate is concentrated by evaporation, a slow stream of washed H_2S gas is then passed through it for some hours, after which it is allowed to cool, and the precipitate allowed to settle. The precipitate is filtered, dried, and weighed. Each part by weight of the sulphide corresponds to 1·1681 parts of anhydrous corrosive sublimate. The second, or dry method, consists in the adaptation of the principle of electrolysis. The clear liquid as above prepared is taken, weighed pieces of gold-foil are introduced into a platinum vessel with the liquid, and the mercury is deposited upon these pieces of gold-foil. As one piece is covered, a second is substituted, if required. Thereafter, the foil being washed in water, alcohol, and ether respectively, is dried and weighed, is then put into a piece of hard glass tubing, and the mercury driven off by heat. The foil, after having cooled, is again weighed; and from the figures so obtained, the total mercury, as metallic mercury, or as corrosive sublimate, may be calculated by difference.

Medico-Legal Trials for Poisoning by Mercury.

1. Walsh—tried at Kilkenny Summer Assizes, 1850.
   Poison administered in whisky.
2. Welch—tried at Worcester Summer Assizes, 1845—(*Med. Gaz.*, vol. xxxvi. p. 608).
   Poison applied externally—Corrosive sublimate.
3. Robertshaw—tried at Carlisle Lent Assizes, 1845.
4. Daniel—tried at Exeter Lent Assizes, 1855.
   Poison—Ammonio-Chloride of Mercury.
5. E. Smith—tried at Leicester Summer Assizes, 1857.
   Poison—Nitrate of Mercury.
6. Moore—Lewes Lent Assizes, 1860.
   Poison—White precipitate.

Lead.

The principal salts of lead which produce toxic effects are the acetate (in powder or in solution), the oxide, in the form of diachylon, the carbonate or white lead, the tetroxide or red lead, and yellow chrome or chromate of lead. The chloride and nitrate, not being easily procured by the public, do not bulk so largely in medico-legal work. All lead salts are less irritant in action than those of arsenic, etc., already considered, but the acetate and chromate are more irritant than the others. Poisoning by lead in the chronic form is very common in those industries in which lead is used or handled in one form or another; as in lead-grinding works, potteries, paint manufactories, japanning and lacquer works; dye works in which lead chromate is used, coach-

Table showing the Differences between Arsenic, Antimony, and Mercury in respect of Deposits on Copper-Foil in Reinsch's Test, and of Deposits on Porcelain between the two former in Marsh's Test.

	Copper-Foil Deposit.	Character of Sublimate.	Porcelain Deposit.	Reaction with Chlorinated Lime.	Reaction with NH_4HS.
Arsenic	Steel-grey, with metallic lustre.	Octohedral crystals of As_2O_3.	Three concentrated rings: (1) whitish; (2) brownish; (3) black, metallic; from without inwards.	Dissolves easily.	Dissolves sparingly.
Antimony	Violet-red, violet, or black.	Amorphous particles of antimonous oxide.	Black, and sooty in appearance.	Does not dissolve.	Freely soluble.
Mercury	Silvery, and metallic in lustre.	Tiny globules of metallic mercury.	...	..	...

Table showing Differences between Crystalline Forms of, and the Effect of Heat upon, Arsenious Acid, Tartar Emetic, and Corrosive Sublimate.

	Crystalline Form	Effect of Heating on Platinum Foil.
Arsenious Acid	Octohedral crystals.	Sublimes in white vapour, without residue.
Tartar Emetic	Rhombic octohedral crystals.	Becomes charred; leaves a black residue.
Corrosive Sublimate	Rhombic prisms.	Melts; sublimes in white vapour; no residue.

making, tinning and enamelling works, plumbing, file-making, and in electric accumulator works. Cases of lead poisoning may occur in ways quite unexpected. A case is recorded[1] where a habitual beer-drinker developed the chronic symptoms. It appeared, on inquiry, that he got his liquor regularly on draught from a certain beer-shop, that the beer was pumped from the cellar to the bar by lead pipes of twenty feet in length, and, on examination of the pipes, that they were found much worn. Samples of beer drawn from this tap gave unmistakable evidence of lead.[2] We have seen two cases in domestic life, in which the cause was a cracked frying-pan, the cracks in which had been soldered with lead, which had been partly dissolved by the fat of ham. The use of diachylon as an abortifacient[3] being now comparatively common, it may be necessary to examine excretions, or the bodily organs for lead, where death results.

Symptoms of Acute Poisoning.—Lead acetate and other lead salts in large doses produce an astringent metallic taste in the mouth, a burning, pricking sensation in the throat and gullet, and a like sensation in the stomach with pain, succeeded, after an interval, by nausea and vomiting, the vomited matter being latterly streaked with blood. Diarrhœa may supervene early. There is much dryness of fauces and great thirst. Colicky pains develop in abdomen, the abdominal walls are tense and contracted, and the pains are relieved by pressure. Instead of looseness of bowels, there may be constipation; if, however, stools are passed, they are black in colour and have a very offensive odour. Symptoms of collapse set in before death. Should, however, the case be protracted, pains in calves of legs and thighs develop, and there are likely to be numbness and paralysis of limbs. Coma or convulsions may, in these cases, precede death.

Symptoms of Chronic Poisoning.—These may be summed up as follow: colic, which is very intense; general malaise, prostration, and great debility; obstinate constipation; gradual emaciation; appetite lost, or capricious; face sallow; and, in most cases, there is a blue line on the gums. This is not constant, however. Sir W. Gower records a case in which it was absent.[4] The nervous symptoms almost characteristic of this poison are: "wrist-drop,"—due to paralysis of extensors and supinators of forearm, accompanied not infrequently by muscular degeneration and wasting. In several cases seen by us in pottery-dippers, the scapular muscles and those of the arms were very much wasted. There may be paralysis of the limbs, or head symptoms in odd cases.

The following figures will indicate the prevalence and extent of industrial lead poisoning. In 1896, of 1050 cases which were reported to the Chief Inspector of Workshops and Factories of poisoning by lead, phosphorus, and arsenic of industrial origin, and of anthrax, 1030 were caused by lead. Of these, 432 occurred from the use of lead in glazes in china and earthenware works, 239 in white lead manufactories, and the remainder in glass workers, metal smelters, tin workers,

[1] *B. M. J.*, vol. ii. 1900, p. 1313.
[2] *The Lancet*, vol. ii. 1889, p. 126. (Beer-poisoning in Liège from same cause.)
[3] *B. M. J.*, vol. ii. 1901, p. 72. (For other references see Criminal Abortion, p. 287.)
[4] Ibid., vol. ii. 1898, p. 1504.

enamellers, file makers, paint and colour mixers, coachmakers, and others.

Cicconardi has suggested a method of diagnosing lead poisoning where the cause of colic—often the main symptom—is obscure, viz.: to paint the skin of the body with a 6 per cent. solution of sodium sulphite. If lead be the cause, the skin assumes a darkened appearance over the painted parts. It is well worthy of trial.

Post-Mortem Appearances.—After acute poisoning, the appearances are mainly those of gastro-enteritis. The mucous membrane of stomach may be softened, and there may be eroded patches. In deaths after chronic poisoning, the intestines are found contracted and thickened, and cirrhosis of kidneys is commonly present. There is likely to be marked atrophy of muscles of the shoulder, arm, or forearm.

Fatal Dose.—This has not been accurately determined; but Christison has recorded a case in which two drachms, taken in two separate doses of one drachm each with several hours' interval, produced serious symptoms, but after treatment the man recovered. In another case, recovery followed the taking of one pennyworth of sugar of lead dissolved in hot water.[1]

Fatal Period.—Children of four and six years respectively who had taken Goulard's Extract, died within 36 hours; and a man, after having taken the same preparation, died at the end of three days.

Treatment.—The indication is to empty the stomach, either by emetics, or preferably by stomach-tube. The in-going water should be mixed with the sulphates of soda or magnesia, or dilute sulphuric acid, with which the insoluble sulphate will be formed, but which can be washed out by lavage. After preliminary danger is over, demulcent drinks and milk should be given, and the treatment regulated otherwise as the symptoms indicate.

Chemical Analysis.—When a piece of the acetate is heated on platinum foil, it first melts, then solidifies, and then becomes darkened in colour, giving off fumes of acetic acid.

The liquid tests applicable to lead in solution are the following:—

1. Dilute H_2SO_4 gives a white P. of the sulphate, which is insoluble in HNO_3, but soluble in HCl, and in excess of liquor potassæ, and in ammonium acetate.
2. A solution of KI, gives a bright yellow P. of the iodide, soluble in liquor potassæ, and in boiling water.
3. H_2S or NH_4HS, gives a black P. of the sulphide.
4. K_2CrO_4 gives a yellow P.

Detection in Organic Mixtures.—Acidulate the organic substances, reduced to fine proportions, with nitric acid, heat for some time, then permit to cool; filter, wash residue, and mix washings with filtrate; concentrate filtrate; pass H_2S; place mixture in warm place, to allow precipitate to settle. After which, decant supernatant fluid, collect precipitate on tared filter, thoroughly wash, dry on water-bath, and weigh. One part of sulphide is equivalent to ·9331 part of lead oxide, and 1·5837 parts of acetate of lead.

The electrolytic method is better adapted for the detection of minute quantities of lead, as for example in the urine or fæces, or

[1] *B. M. J.*, vol. i. 1900, p. 1221.

in vomited matter; the urine may be evaporated to a viscous state, the others, finely broken up, are treated in the same way, after HCl is added, the mixture heated, and pinches of powdered chlorate of potash also added, as necessary, to break down organic matter. The heating is continued until the odour of chlorine disappears, after which it is filtered, and the filtrate allowed to cool. The filtrate is then placed in the outer cell of a two-celled arrangement, not unlike a dialyser, the bottom of which is formed of vegetable parchment, the outer cell containing distilled water acidulated with H_2SO_4. Into the inner cell is placed a piece of platinum foil measuring about 50 c.m. square of exposed surface, which is connected with the cathode or positive pole of four Grove cells, and into the outer cell is placed a like-sized piece of platinum foil connected with the anode or negative pole. These pieces of foil are so placed in relation to one another that they are only separated by the parchment. The galvanic circuit being now closed for some hours, any lead in the filtrate will be deposited on the platinum foil connected with the cathode in the inner cell. The foil is then removed, carefully washed, and the metallic lead dissolved by dilute nitric acid, aided by heat, after which the solution is concentrated until most of the free acid is driven off, dilute sulphuric acid is added to throw down the sulphate, alcohol being also added to expedite precipitation. The precipitate is allowed to settle for 24 to 36 hours, filtered on a tared filter, washed with water containing 12 per cent. of alcohol, dried, ignited, and weighed. One part of sulphate is equivalent to 0·68319 part of metallic lead, and to 1·25 parts of acetate of lead.

Copper.

All copper salts when taken in large doses exercise toxic effects; even in smaller doses they may be legally considered as "noxious things." Probably the most poisonous are the sulphate or blue vitriol, and the subacetate or verdigris. They are seldom used for criminal purposes because of their striking colour—blue or green. The sulphate, however, has been used to procure abortion. Copper, it must be borne in mind, exists in a variety of objects in nature, even in some which are used as food, but only in very minute quantities. In the metallic form, as when bronze coins are accidentally swallowed, it does not usually exercise any appreciable effect upon the system. Workers in copper are said to suffer occasionally from toxic effects produced by the inhalation of copper dust. A case is recorded[1] in which the death of a boy, aged 13, was attributed to the inhalation of bronze-powder, which consists of an alloy of copper in fine powder. He suffered from sickness, pain in bowels, and great distension of abdomen, but with no diarrhœa. Post-mortem examination revealed that he died from peritonitis, and chemical analysis of the viscera, that they contained copper. The sulphate is used for the purpose of giving an artificial colour to preserved vegetables such as peas and others. From a personal and family use of such preserved peas over continuous lengthy periods, we have not discovered any unusual effect.

[1] *B. M. J.*, vol. ii. 1880, p. 138.

From the public health point of view, the question has frequently been tried in Courts of Law whether peas, so greened, are prejudicial to the health of the consumer, and in contravention of the Foods and Drugs Acts. We have been engaged in three or four cases of this kind, and have made many experiments with respect to the precise combination which copper forms with the substance of the pea, to the digestibility of the product, both *in vitro*, and in our own person and that of others, with respect to prejudice to health. From these experiments, we have arrived at the following conclusions: first, that the copper unites with the legumin—the vegetable albumin—to form a leguminate of copper, just as it forms with animal albumin an albuminate of the metal; second, that the quantity of copper which can so be taken up by peas to form this combination in no way affects their digestibility in the average person;[1] and, from personal experiment in the eating of such peas for three weeks daily at dinner, that neither could any taste of copper be perceived, nor was any bodily discomfort experienced; further, that the same facts were noted as the result of experiment upon the children of our own family. Tschirch[2] is of opinion that the copper primarily unites with a derivative of chlorophyll of the peas—phyllocyanic acid—to form the phyllocyanate of copper, and, secondarily, should any excess of copper have been added, that it combines with the legumin to form the leguminate. From the difference in judgments by magistrates in different cases, the whole legal question as to the innocuousness or harmfulness of the use of copper within certain limits is very unsettled. In two Glasgow cases, judgment was given for the defenders, and in one of these in which an appeal was taken to the Court of Session, the judgment of the Sheriff was upheld. In a Liverpool case, in which we gave evidence, judgment was also in favour of the defendants. But in many other cases in England judgment has been in favour of plaintiffs.

The Committee appointed by the President of the Local Government Board in July 1899 to Inquire into the Use of Preservatives and Colouring Matters in Food, in their Report recommended that the use of copper salts in the so-called greening of preserved foods should be prohibited. To this finding one of the Committee—Dr. Tunnicliffe—dissented, on the ground that copper formed with the substance of the pea a relatively insoluble and unabsorbable compound, and that he could not conceive conditions under which a small quantity of copper so combined in properly preserved peas could be injurious to any consumer to whom the peas themselves would be harmless. These opinions which he gives are founded upon the evidence of witnesses called before the inquiry, and from certain experiments he himself made upon children with peas greened with copper with the object of discovering the extent to which the copper ingested was absorbed and retained by the human body (*vide* Report of Committee, p. 312 of Appendix).

Dauscher reports in a Vienna medical journal[3] a case of poisoning by verdigris in a cook, who, engaged in drawing wine from a cask by means of a brass tube, drank some. In ten minutes afterwards, she was seized with severe pain in stomach and vomiting, and became unconscious, with the signs of shock. Slight icterus appeared the following day. The wine from the brass tube was found on analysis to contain "a considerable quantity" of copper, while that of the cask had none.

Symptoms.—If it be assumed that ℥ss of the Sulphate or Subacetate has been taken, the following are the symptoms which may be looked for: pain and heat in mouth, gullet, and stomach; bluish or greenish coloration of mucous membrane of mouth; vomiting, which exhibits bluish or greenish vomit; there may be violent diarrhœa with bluish or greenish stools accompanied by colicky abdominal pains; convulsions and cramps of limbs may sometimes be seen. If the case

[1] Charteris and Snodgrass, *The Lancet*, vol. i. 1892, p. 190.
[2] *Das Kupfer vom Standpunkte der Gerichtlichen Chemie*, 1893.
[3] See *The Lancet*, vol. i. 1889, p. 1155.

go on to a fatal issue, death is preceded by convulsions, paralysis, or coma. In chronic poisoning, which is but rarely observed even among workers in the metal or its salts, the main indications are on a parallel with salts of lead. There are evidences of progressive emaciation, gastro-intestinal catarrh—vomiting, gastric irritability, loss of appetite, looseness or constipation of bowels,—a coloured line on the gums, and, perhaps, a coloration of the teeth, the colour being bluish, greenish, or purplish. The evidences of implication of the nervous system are also much alike to those from lead poisoning, viz.: peripheral neuritis, degeneration, and atrophy of muscles of shoulder, arm, and forearm, with wrist-drop in some cases.

Post-Mortem Appearances.—Perhaps the most striking appearance is the bluish or greenish appearance imparted to the lining wall of stomach. The mucous membrane is swollen, softened, and inflamed, and, it may be, ulcerated in patches. The intestinal mucous membrane shares the same appearances; and in some few cases, perforation of intestine has been seen. The coloration by bile may be mistaken for that of copper, but on touching the latter with ammonia, the blue colour becomes intensified, or the green is changed to blue.

Fatal Dose.—Half an ounce of subacetate[1] and upwards. One ounce of the sulphate in an adult. A child has been killed by twenty grains of the subchloride. Recovery, however, has followed the swallowing of an ounce.[2]

Fatal Period.—Four hours in a child which swallowed an unknown quantity of the sulphate. Twelve hours in the case of a man who took one ounce.

Treatment.—As in lead poisoning: the use of the siphon-tube and free lavage with albuminous and demulcent fluids.

Chemical Analysis.—The greenish or bluish appearance of vomit gives a clue to the poison. The blue colour is quite evident in 500 grains of a solution containing only the $\frac{1}{100}$th part of its weight of copper oxide. The liquid tests for the detection of copper in solution are as follows:—

1. Dilute NH_3 gives a bluish-white ppt. soluble in excess, and leaving a deep blue colour.
2. H_2S and NH_4HS give a deep chocolate-brown ppt., or, if the quantity of copper be small, a light-brown coloration only.
3. Ferrocyanide of Potassium gives in very dilute solutions, a claret. or port-wine red ppt. soluble in ammonia to a bluish-green liquid, which distinguishes it from a nearly similar reaction with salts of uranium, which, however, turns yellow on addition of excess of ammonia.
4. If a polished steel needle be put into an acidulated copper solution, the copper is deposited on the needle, as a reddish-yellow deposit of the metal.
5. If the acidulated copper solution be placed in a platinum capsule, and a piece of zinc-foil be brought in contact with the capsule through the medium of the fluid, the metallic copper is deposited on the sides of the platinum vessel.

Examination of Contents of Stomach.—Placed in a large porcelain dish, the material is strongly acidulated with HCl, and water added if necessary. The mixture is then heated for some time, and after

[1] Taylor, "On Poisons," p. 524.
[2] Stillé, *Mat. Med.*, vol. i. p. 325.

cooling is filtered; the filtrate is then concentrated, and H_2S is slowly passed through it for some time. The sulphide is allowed to settle, is then passed through a filter, washed, and then dissolved by dilute HNO_3 with the aid of heat. Sulphuric acid is cautiously added, drop by drop, to throw down the sulphate, which will be recognised by its blue colour. It is then carefully evaporated to dryness. It may then be dissolved in water and the liquid tests used for corroboration.

Quantitative Estimation.—After solution of the organic matter has been obtained, the copper may be thrown down either by H_2S, as the sulphide, or by potassium hydrate solution. In the former case, after filtering the precipitate, it is dissolved in strong HNO_3; the solution is evaporated to dryness in a tared platinum capsule, then heated to redness to drive off the nitric acid, leaving cupric oxide in the capsule. One part of cupric oxide is equivalent to 0·7985 part of metallic copper. In the latter case, the ppt. produced by addition of potassium hydrate is filtered on an ash-tared filter, washed with warm water, and dried. The ppt. is detached from the filter into a tared platinum vessel, and strongly ignited. The remains of the ppt. on the filter is burned separately with the filter-paper, and the ash added to the capsule. After cooling in a desiccator, it is quickly weighed as cupric oxide, after deduction of ash of filter used.

Zinc.

The toxic effects of zinc are confined to the use of two salts of the metal, viz.: the sulphate or white vitriol ($ZnSO_4$, $7H_2O$), the action of which is irritant, and the chloride ($ZnCl_2$, $2H_2O$), which is corrosive, and which has been already noticed (p. 412). Zinc fumes, also, exercise toxic action upon persons engaged in such occupations as zinc-smelting. Mackintosh gives an account of a fatal issue in a woman of fifty-three after having taken at least one ounce of the sulphate. Her symptoms were: severe pain in stomach and bowels, pallor of face, coldness of limbs, cold sweats, irregularity of pulse, and purging. She had only vomited about one teaspoonful of fluid. She died about twenty-four hours after taking the poison. The post-mortem symptoms, generally, were those of asphyxia. The gastro-intestinal mucous membrane showed patches of intense inflammation, which was more marked, however, in the small intestines, these being inflamed throughout. The congestion of the latter was indeed so marked that it was visible through the muscular wall.[1]

Symptoms: from the Sulphate.—These are mainly of gastric disturbance, and consist of violent vomiting, pain in stomach and abdomen, diarrhœa, and, where a considerable quantity has been taken, symptoms of collapse. The sulphate has been taken in mistake for Epsom salts in a dose of one and a half ounces, causing a fatal effect.[2] In this case, the vomiting and diarrhœa were almost incessant for half-an-hour, and continued at intervals for three hours. The pulse was small and frequent, there were great prostration and anxiety, coldness of body, and violent pain in abdomen and limbs.

1 *B. M. J.*, vol. ii. 1900, p. 1706.
2 *Brit. and For. Med. Chir. Rev.*, April, 1849.

From the Chloride.—The symptoms are of a somewhat different kind, because of the corrosive character of this salt. They are: an immediate burning sensation in mouth, throat, gullet, and stomach; violent, and, perhaps, bloody vomiting; diarrhœa, and symptoms of shock.

The symptoms of chronic poisoning are closely allied to those of lead and copper.

Gimlette[1] has recorded the facts of an epidemic of zinc poisoning through drinking contaminated water, among Sikh and Pathan soldiers in the Malay Peninsula. The water-supply was obtained from the rainfall which was collected from the galvanised iron roofs of the barracks by means of zinc gutters, and was stored in a galvanised iron tank. There was no provision for separating the first part of the rainfall from the succeeding. From March 1898 till April 1900, in all 329 men and women were affected. The chief symptoms were dysenteric in character, viz.: diarrhœa, colic, sometimes vomiting and violent retching, the vomited matter sometimes streaked with blood, stools containing ropy mucus and blood, loss of flesh, dyspepsia, anæmia, and in certain cases, atrophy of muscles of calves and thumbs. The gastro-intestinal symptoms, however, predominated over the nervous. When suspicion centred upon the water as the cause, it was analysed, and was found to contain zinc. The water collected directly from the galvanised iron roof contained 1·115 parts per 100,000, and that taken from the tank, ·482 parts. This is accounted for by the fact, that in the former, the zinc was present in the form of carbonate formed by the CO_2 in the rain-water, but that on standing in the tank the CO_2 being partially liberated, the zinc was thrown out of solution as the oxide. A like outbreak occurred at Cwmfelin, near Llanelly, some years ago,[2] and the quantity of zinc found in the water there was over fifteen times greater than that found in the tank in the foregoing case. Other cases are to be found recorded in the following references.[3]

Post-Mortem Appearances.—In the case where the large dose of sulphate caused death, the appearances were as follow: the inner surface of stomach was covered with yellowish, viscid material, below which the wall of the organ was ochrous yellow in colour, the mucous membrane being softened into a gelatinous condition. In other cases, patches of ecchymosis, and erosion have been observed. The small intestine shared the same appearances. From the chloride, signs of corrosion are present. In a case where death resulted from Burnett's fluid, the mucous membrane of mouth, throat, and gullet was found white and opaque, the stomach was hard and leathery, and contained a fluid not unlike a mixture of curds and whey. In another case,[4] the stomach was quite destroyed, its cavity resembling the interior of a chronic abscess.

Fatal Dose.—One and a half ounces of sulphate. One ounce of Burnett's fluid killed a woman. Recoveries from the former, however, are more common than deaths.

Fatal Period.—Thirteen and a half hours from foregoing dose of sulphate. Four hours in above case from one ounce of Burnett's fluid.

Treatment: as for Lead.—Where the chloride has been taken, an alkaline carbonate may be used with benefit.

Chemical Analysis—Liquid Tests.—(1) H_2S in neutral and alkaline solutions throws down a white ppt. of the sulphide, soluble in the mineral acids.

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[1] *B. M. J.*, vol. ii. 1901, p. 615.
[2] *The Lancet*, vol. ii. July 29, 1893.
[3] *The Lancet*, vol. ii. 1897, p. 157; idem, vol. ii. 1896, p. 766.
[4] *Brit. Med. Jour.*, vol. i. 1887, p. 1387.

(2) Ferrocyanide of Potassium gives a white ppt. insoluble in mineral acids.

(3) Ferricyanide of Potassium gives a yellow, reddish-brown, or greenish ppt. soluble in potash and ammonia.

Quantitative Estimation.—Heat solution to about 180° F.; add dilute solution of Sodium Carbonate until ppt. no longer forms; then boil for a few minutes; allow ppt. to settle; filter; wash with hot water; dry; ignite. The zinc now exists as oxide. One part of zinc oxide is equivalent to 0·8026 part of metallic zinc.

Tin.

The main danger of poisoning by this metal arises from "canned" goods, particularly those which contain acid fruit juices, or, occasionally, from "loaded" fabrics. Jolles gives the facts of a case in a woman, in whom toxic symptoms apparently arose from the wearing of silk stockings which were "loaded" with tin chloride ($SnCl_4$). It appears that this metal is added to the silk for the purpose of giving it weight, and especially to silk of delicate colours. On analysis of the stockings, tin was found in considerable quantities, and the metal was also detected in the patient's urine. The symptoms were: partial paralysis of legs, accompanied by anæsthesia, coldness, and ataxic gait; emaciation; urine contained albumen and tube casts.[1] In like manner lead poisoning may originate. In addition to mineral poisoning from canned goods, cases of ptomaine poisoning are by no means uncommon, so that no one is justified in diagnosing mineral poisoning because of irritant symptoms developing in those who have consumed such foods, not, indeed, until mineral poison has been found in such amount as to justify the conclusion that this alone was the cause of the mischief. In the few cases which have been recorded, tin salts were found in the fluids of the "canned" fruit.[2] In one case 1·9 grains of stannic oxide per ounce of cherry juice were found, and in another, the juice of pears contained a larger amount.

Symptoms.—These are mainly indicative of irritant poisoning, and relatively to the amount of tin found, are very severe; in other words, tin is more toxic than lead, copper, or zinc, for equal amounts.

The *Treatment* is the same as for lead or other irritant poison.

Chemical Analysis.—The contents of the stomach, or of a "can" of fruit having to be examined, the organic matter, having been reduced to a thin pulp, is treated by hydrochloric acid, is heated, and powdered potassium chlorate added to it in pinches as required until the fluid becomes homogeneous. H_2S gas is then passed through it, and the sulphide precipitated; the ppt. is allowed to settle and cool, is thereafter filtered through an ashed filter, washed, and dried, and then scraped into a platinum vessel in which it is ignited strongly to convert the sulphide into the oxide. The filter-paper is ignited separately, and the ash added to the platinum capsule. After cooling, the capsule and contents are weighed, and, after the necessary deduction for the ash of filter-paper, the weight represents the amount of tin in the weighed quantity of organic substance treated. One part of the oxide is equivalent to 0·7838 part of metallic tin.

[1] *Wien. med. Presse*, Mar. 17, 1901.

[2] *B. M. J.*, vol. i. 1890, p. 883; *The Lancet*, vol. ii. 1888, p. 1129.

In testing liquid solutions, the following tests may be used :—

1. H_2S gives with stannous salts a dark brown, and with stannic salts, a yellow ppt. or coloration.
2. Mercuric chloride and dilute HCl give with stannous chloride, first, a white precipitate of mercurous chloride, which turns grey, and later, black, owing to the ppt. becoming changed into metallic mercury.
3. $AuCl_3$ (gold chloride), gives a beautiful purple ppt. or coloration—the purple of Cassius.

Metallic Salts.

There are certain salts of the metals, which, by reason of their producing serious toxic effects, even death itself, after being swallowed in mistake for Epsom and Rochelle salts, deserve some consideration. These are salts of Barium, Nitrate of Potash or Saltpetre, and Potassium Chlorate.

Barium Salts.—The principal salts are the chloride, nitrate, and the carbonate, the first being the most poisonous. These are constituents of certain rat poisons. Taylor [1] quotes a case from Wildberg, where a woman, aged 23, took a dose of about half an ounce of the chloride dissolved in warm water. Her *symptoms* were as follow: nausea and vomiting, the vomit consisting of a watery mucus; convulsive movements of hands and feet; these symptoms becoming intensified, she died at the end of two hours in violent convulsions. To these symptoms must be added diarrhœa with tenesmus, grave signs of shock, loss of motor power and sensation; the heart is embarrassed in its action, and the breathing laboured and slow. It would thus appear as if this poison acted not only locally, but also, on being absorbed, on the brain and nervous system.

Fatal Dose.—One teaspoonful has destroyed life. A man died who took a mouthful of a solution containing 130 grains of the chloride.[2]

Fatal Period.—From two hours upwards.

The nitrate and carbonate [3] have also caused fatal results, although cases have recovered from the latter salt.

Chemical Analysis—

1. *Flame Test.*—The characteristic green flame reveals Barium at once in an organic fluid.
2. Dilute H_2SO_4 gives a white heavy-looking ppt. of the sulphate, which is insoluble in HNO_3.

Quantitative Estimation.—This is based on the insoluble character of the Sulphate.

Nitrate of Potash.—This salt has frequently destroyed life. It is found in well-formed prismatic crystals. Taken accidentally, as it usually is, in mistake for Epsom salts, the quantity is generally large.

Wolstenholme records a case in which a man took by mistake for Epsom salts an (avoirdupois) ounce of this salt. He at once experienced great pain in the stomach, became sick, but only began to vomit four hours after taking it. He then vomited freely, however,

[1] *Op. cit.* p. 220.
[2] Stern, *Zeitschrift f. Med. Beamte*, 1896.
[3] *Med. Gaz.*, vol. xiv. p. 448.

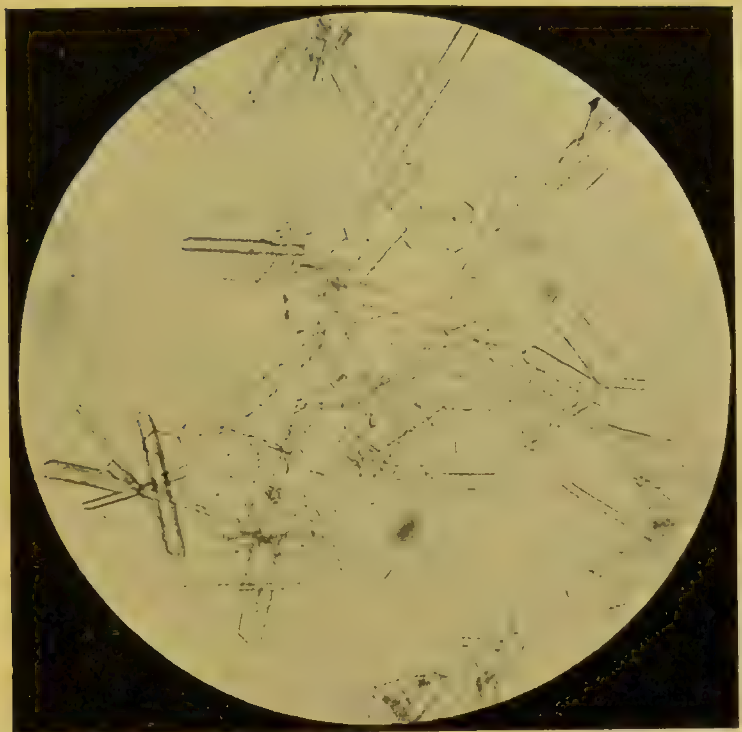

FIG. 102.—Photo-micrograph of crystals of Potassium Nitrate. × 500 diameters. (Author.)

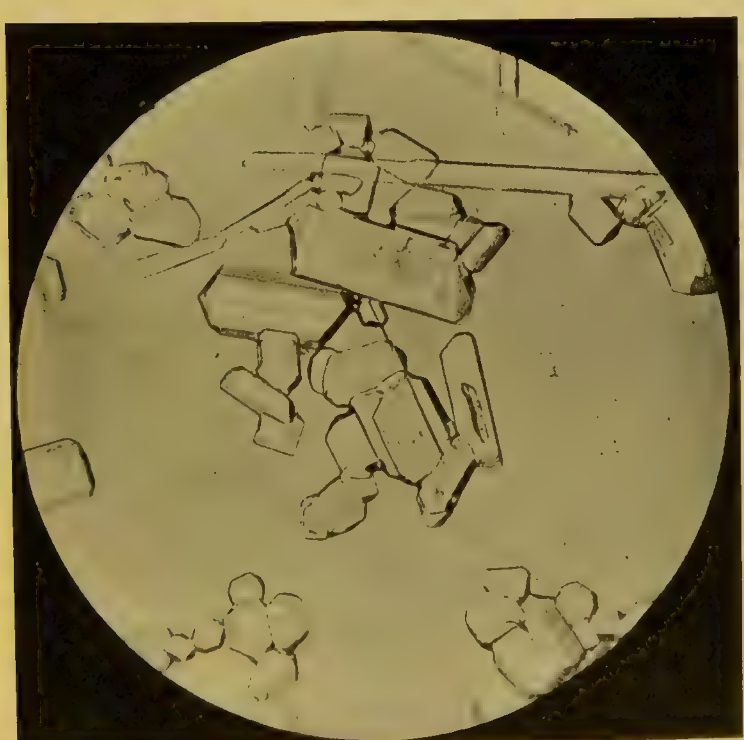

FIG. 103.—Photo-micrograph of crystals of Magnesium Sulphate × 500 diameters. (Author.)

the vomit containing a quantity of dark "coffee-grounds" material. After the administration of purgatives, he passed tarry stools. For the first four hours he had an intense desire for micturition. He gradually recovered.[1]

Symptoms.—The symptoms which followed the taking of one ounce were as follow: vomiting, accompanied by severe gastric pain, and diarrhœa with bloody stools; symptoms of collapse; lividity of the face; insensibility; followed by death.

Post-Mortem Appearances.—The mucous lining of stomach is of a bright red, or brownish-red colour; indeed, it has been likened to scarlet cloth. The vessels of the mucous membrane are highly reddened and injected, as if by vermilion. The blood is fluid, and seems hyper-oxygenated.

Fatal Dose.—One hundred and twenty grains killed a man of 40 years. This may be said to be exceptional, because it has been administered medicinally in from three to five drachm doses,[2] or in even larger doses, with no toxic results. The usual fatal quantity is about one ounce, although recovery has followed even that quantity.

Fatal Period.—This is usually comparatively short, and varies from two or three to thirty-six hours.

Treatment.—Siphon-tube; free lavage; hypodermic injection of stimulants; warmth to body; and treatment of prominent symptoms.

Chemical Analysis.—There is no characteristic chemical test. Perhaps the easiest and best mode of testing is to filter a portion of the contents of the stomach, concentrate one portion, and with it saturate a small piece of bibulous paper, and dry. This, when ignited, burns like touchpaper. Evaporate the other portion nearly to dryness, allow it to crystallise out over sulphuric acid in a desiccator, and examine for the characteristic crystals.

Chlorate of Potassium ($KClO_3$).—This salt is a very lethal poison. In some respects, it might be mistaken for poisoning by arseniuretted hydrogen, or for such diseases as hæmoglobinuric fever. If blood be mixed *in vitro* with this salt, it becomes thicker in consistence like syrup, and the spectrum of oxy-hæmoglobin is changed into that of met-hæmoglobin. When taken into the living body in large doses, the salt produces profound symptoms, which may be summarised as follow: severe vomiting, pain in stomach and intestines, signs of shock, cyanosis, oliguria, or, it may be, anuria. Should any urine be passed, it is dark like porter, containing in solution the colouring-matter of the blood, renal tube-casts, and albumen. Jaundice, of an unusual hue, is commonly present. It is an open question whether this is hepatogenous or hæmatogenous. The following may be taken as typical cases.[3]

The first was that of a woman, aged twenty, who took by mistake for Rochelle salts two tablespoonfuls of the chlorate. About twenty-four hours thereafter, her symptoms were these: she was profoundly prostrated; her temperature, 99° F., and pulse, 136; respirations, 32 per minute. The body surface was cyanotic, the breathing rapid but not laboured, and the pulse rapid but not feeble. She had vomited freely, and was still vomiting after admission to hospital. Two

[1] *B. M. J.*, vol. i. 1882, p. 304. [2] *L'Union Médicale*, June 1847, p. 274.
[3] *New York Med. Jour.*, July 21, 1888.

hours later, the temp. rose to 104° F. Three dark-brown motions had been passed, and dark-coloured urine was voided involuntarily. The urine contained many blood-discs, large masses of altered hæmoglobin, and much albumin. Next day, her skin, conjunctivæ, and lips had an extraordinary colour—something between anæmia cyanosed and a sepia-brown chocolate tint. She died in 37 hours after the poison had been taken, having been in a state of stupor up till her death. On post-mortem examination, the blood in the large vessels was fluid and of a very dark chocolate colour. The heart was soft and flabby ; the lungs normal, but on section very brown in colour. The spleen was large, firm, and of a very distinct chocolate hue ; the kidneys large, containing chocolate-coloured blood. The bladder contained three ounces of urine of a dark-brown colour. Spectroscopic examination of the blood gave the spectrum of met-hæmoglobin. Microscopic examination of tissues of heart showed extensive fatty degeneration of muscle, and the tubules of kidney filled to distension with broken-down corpuscles and blood-pigment.

The second case was that of a man, aged 53, who took an overdose of this salt. His symptoms were as described. He died comatose. On post-mortem examination, the appearances were as the foregoing, and, in addition, the gall-bladder was full of thick, very dark-green bile. Another fatal result following the taking of seven drachms, is recorded.[1] Jacob[2] has recorded another case where a woman took about 25 grammes (about 385 grains), the symptoms being as described. He points out that this poison destroys the red blood-corpuscles, dissolving the hæmoglobin out of their stroma and liberating it into the liquor sanguinis, as indicated by the reduction in number of red corpuscles per cub. millimetre, and in amount by 20 per cent. of hæmoglobin. Another case indicates its toxic effects upon children. Three of them took altogether between 3 and 4 drachms, and one died.[3]

Fatal Dose.—About 380–390 grains, and upwards.

Fatal Period.—This usually extends into days.

Treatment.—Evacuate contents of stomach by siphon-tube and free lavage. Bleeding from the arm, and transfusion of blood from the body of another.

Chemical Analysis.—The poison may be obtained from organic matters by dialysis.

In addition to these salts of potash, the sulphate, and bi-tartrate have caused fatal results in isolated cases.

Pyrogallic Acid ($C_6H_6O_3$).

This substance which is now so commonly used by reason of the spread of amateur photography, and in the manufacture of hair dyes and marking inks, has very toxic properties, not only when swallowed, but even when it is absorbed through the skin. Some cases of poisoning from both causes have already been recorded. Its toxic action is very serious, since like several other poisons, as arseniuretted hydrogen, chlorate of potash, and others, it has a hæmolytic action, that is, it destroys the red corpuscles, liberating the hæmoglobin of the stroma of the discs into the liquor sanguinis. From this effect follow dyspnœa, insensibility, subnormal bodily temperature, bloody urine, and other symptoms. Neisser[4] records a case in which toxic symptoms followed the external use of an ointment containing ten per cent. of the acid, in the treatment of psoriasis. Six hours after its application to one half of the body of the patient—who was, but for the skin disease, a healthy strong man—

[1] *The Lancet*, vol. i. 1879, p. 206.
[2] *Berl. klin. Woch.*, 1897.
[3] *The Lancet*, vol. i. 1879, p. 206.
[4] *Annal. d'Hyg.*, pub. May 1881.

he was seized with violent shivering, vomiting, and intense collapse. He died on the fourth day, his death being preceded by coma, and a very low bodily temperature. During the time he lived, he passed but little urine, which was dark-brown in colour, was very thick, contained no blood-corpuscles, but a considerable amount of hæmoglobin. On post-mortem examination, the kidneys were of a uniformly bluish-black colour, and the blood of the body generally had a dirty brownish-red tint, and contained *débris* of red discs. Reilly[1] records the facts of a case in which a woman of 32 years swallowed, with suicidal intent, about half an ounce of the acid dissolved in water. Her symptoms were these: her face generally was of a dirty-grey colour, except the lips, cheeks, and ears, which were dark blue. Her skin was cold, the heart acting feebly, but she was conscious. She had been vomiting for two hours. Diarrhœa then set in, which was continuous for about twelve hours. Her urine consisted principally of blood. Next day intense headache supervened, along with drowsiness. In this condition she continued till the following day, when she became comatose, and died sixty-eight hours after the onset of the first symptoms. Post-mortem examination showed all the internal viscera to be intensely congested, the kidneys, of a dark purple colour, the bladder, to contain blood, and the stomach and intestines, patches of congestion. Other cases have been recorded by Dalché,[2] Benerji,[3] and others.

Treatment.—Use of a siphon-tube with free lavage of stomach; inhalations of oxygen; stimulants; maintenance of bodily heat; and if these fail, transfusion of live human blood.

Chemical Analysis.—If any of the acid exists in the contents of the stomach, after drying them, it may be extracted by digestion with alcohol; the alcohol is then filtered and evaporated to dryness; the residue is then treated with water and shaken up with ether, which dissolves the acid: on evaporation of the ether, the acid is left behind. To this the following tests may be applied: (1) On adding lime-water or liq. potassæ, a purple-red colour is produced; (2) with a solution of ferrous sulphate, a bluish-black colour is formed.

[1] *B. M. J.*, vol. ii. 1897, p. 81.
[2] *La Semaine Med.*, 1896.
[3] *The Lancet*, vol. ii. 1892, p. 308.

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however, that this view must be discarded; by adopting suitable precautions, 2-nitroresorcin may be isolated in considerable quantity, as had been previously demonstrated by Matras; the authors' thanks are due to M. Reverdin of Geneva for calling their attention to this work.

Dinitrofluorescein is thus 4:5-dinitrofluorescein; acted on by bromine, 4:5-dinitro-2:7-dibromofluorescein results. This substance closely resembles the original dinitrofluorescein, it dissolves in alkalis with a brown colour, but on warming a blue solution is obtained from which acids precipitate the hydrate $\underset{\diagdown\ CO\cdot O\ \diagup}{C_6H_4\text{———}C}[C_6HBr(NO_2)(OH)_2]_2$.

4:5-Dinitro-2:7-dibromofluorescein has been further characterised by its *diacetyl* derivative, $C_{20}H_6Br_2N_2O_9(C_2H_3O)_2$, m. p. 276°; *dibenzoyl* derivative, $C_{20}H_6Br_2N_2O_9(C_7H_5O)_2$, m. p. 315°; *sodium* salt, $C_{20}H_6Br_2N_2O_9Na_2,2H_2O$.

Dibromofluorescein, $C_{20}H_{10}Br_2O_5$, obtained by Bayer by the limited action of bromine on fluorescein, is evidently also a 4:5-substitution derivative, since nitric acid produces from it a dinitro-derivative quite distinct from the 4:5-dinitro-2:7-dibromo-compound. The *benzoyl* derivative, $C_{20}H_8Br_2O_5(C_7H_5O)_2$, melts at 240—244°. 2:7-*Dinitro-4:5-dibromofluorescein* may be obtained either by the action of nitric acid upon 2:7-dibromofluorescein or of bromine upon 2:4:5:7-tetranitrofluorescein. This substance dissolves in alkalis with a magnificent purple colour not altered by boiling. Nitro-groups only render the pyrone ring unstable if in the ortho-position relatively to its oxygen atom; this is also shown by the action of ammonia, which reacts with 4:5-dinitro-2:7-dibromofluorescein, apparently in a similar manner to that observed by Reverdin in the case of dinitrofluorescein, whilst with 2:7-dinitro-4:5-dibromofluorescein it merely produces an ammonium salt.

The *diacetyl* derivative, m. p. 215°, *dibenzoyl* derivative, m. p. 301°, and *sodium* salt of 2:7-dinitro-4:5-dibromofluorescein have been prepared.

85. "On phosphorus sesquisulphide and its behaviour with Mitscherlich's test." By E. G. Clayton, F.I.C.

Many compounds of phosphorus and sulphur have been described, but of these the only one which has received any application on the large scale is the sesquisulphide, P_4S_3, discovered by Lemoine in 1864. When pure, it is a lemon-yellow, crystalline solid, with a strong odour of hydrogen sulphide, soluble at 15° in 1·6 parts of carbon bisulphide, and igniting in the air at about 100°. Commercially, several qualities of this substance are manufactured. Amongst those which have come under observation have been a coarsely granular, lemon-yellow

powder; a fine-grained, yellow powder of somewhat duller tint; and a grey product, sometimes very impure. The following are typical analyses:

	A. Yellow (fine-grained).	B. Yellow (fine-grained).	C. Yellow (coarse-grained).	D. Grey (finely granular).
Water and volatile matter (loss at 100°, in an atmosphere of carbon dioxide)	0·19	0·18	8·74	7·31
Phosphorus sesquisulphide, P_4S_3	97·86	97·62	84·95	83·34
Red phosphorus	—	—	—	1·81
Phosphoric acid, H_3PO_4	1·30	1·63	2·14	1·23
Sulphur, uncombined (soluble in carbon bisulphide)	—	—	4·17	—
Sulphur, uncombined (insoluble in carbon dioxide)	0·46	0·40	—	0·17
Calcium phosphate	—	—	—	3·35
Calcium sulphate	—	—	—	0·27
Iron oxide, &c.	—	—	—	1·72
Siliceous matter	0·19	0·17	—	0·80
	100·00	100·00	100·00	100·00
Temperature at which the specimen became luminous in the dark	92°	93°	—	58°
Temperature of ignition	94	96	86°	72
Reaction with Mitscherlich's test	negative	negative	distinct	distinct

Mörner has recently stated (*Svensk Farmaceutisk-Tidskrift*, 1901, **12**, 177) that phosphorus sesquisulphide gives "more or less positive results" with Mitscherlich's test for phosphorus. The author has examined various specimens of commercial phosphorus sesquisulphide, and applied Mitscherlich's test to each in the following way: 20 grams of the compounds were distilled with 100 c.c. of 10 per cent. sulphuric acid, in an egg-shaped flask connected with a spiral condenser, the operation being conducted in a dark room. The very small amount of light emitted by the lamp was screened from the condenser and receiver, which were in complete darkness. In each case, 40 c.c. of liquid were distilled over. The results with comparatively pure specimens, such as A and B, were absolutely negative, not the faintest luminosity being perceptible in any part of the apparatus. It is evident that pure, or even approximately pure, phosphorus sesquisulphide gives no reaction with Mitscherlich's test, and that Mörner's results were obtained with samples containing small quantities of phosphorus, or of phosphorous oxide. Very crude specimens of phosphorus sesquisulphide

no doubt occasionally give Mitscherlich's reaction: thus, with the impure specimen, D (tested after being kept for many months in the laboratory), a distinct luminous cloud played about the exit of the condenser, and in the air of the receiver above the surface of the distillate, which had a faint odour of phosphorous oxide. The sample C, which had been kept for nearly three years, and had undergone considerable oxidation, being quite moist, also gave a decided reaction. The distillate from this also smelt distinctly of phosphorous oxide. The specimens A and B, which gave negative results, had been recently made. Even in these samples some oxidation had occurred, but apparently no phosphorous oxide was present. The author is now conducting some experiments with the object of discovering whether exposure and keeping can so induce partial oxidation in, or alter the composition of, pure, or nearly pure, phosphorus sesquisulphide as to impart to it after a time the property of giving Mitscherlich's reaction. Apart from its scientific interest, the point was of considerable practical importance. Meanwhile, the absence both of free phosphorus and of phosphorous oxide from phosphorus sesquisulphide of fair quality and purity and comparatively recent manufacture was clearly indicated by the negative reaction with Mitscherlich's test, and the following circumstances were corroborative as far as they went. Phosphorus sesquisulphide may be subjected to friction in air at a temperature very considerably exceeding the ignition point of phosphorus without becoming luminous, and with a total absence of "phosphorus fume"; it neither ignites nor begins to glow in the dark until a temperature of 92—96° is reached, and the finely divided residue of a solution in carbon bisulphide, evaporated on filter-paper at the ordinary temperature, neither glows in the dark, fumes, nor ignites spontaneously.

86. "Atomic and molecular heats of fusion." By P. W. Robertson.

No satisfactory relationship has hitherto been found connecting the latent heat of fusion of substances with their atomic or molecular weights. In the case of the elements, the following is shown to yield satisfactory results. "For the elements with atomic weights above 40 which do not expand on freezing, the atomic heat of fusion divided by the melting point on the absolute scale into the cube-root of the atomic volume is a constant." That is, $Aw/T\sqrt[3]{V}$ = constant.

The numbers have a mean variation of ± 10 per cent. The only exception is lead, for which the value of the expression is 25 per cent. below the mean.

In the case of the binary inorganic compounds also, the expression $Mw/T\sqrt[3]{V}$, where V is the specific volume of the solid, yields concordant

results. The values of the expression for organic compounds increase with the number of atoms in the molecule, but when compounds of similar constitution are considered, fairly constant results are obtained.

To test these relations, the latent heats of the following substances were determined:

Thallium	= 7·2	Phenanthrene	= 25
Lead	= 6·45	Phenylacetic acid	= 32
Tin	= 14·05	Tribromophenol	= 13·4
Dinitrobenzene	= 29·0	Tribromoaniline	= 14·4
Thiosinamine	= 33·4.		

87. "The preparation of mixed ketones by heating the mixed calcium salts of organic acids." By E. B. Ludlam.

A device for preparing a simple ketone from the calcium salt of the corresponding organic acid was described by Young (*Trans.*, 1891, 59, 623), which consisted in decomposing the salt at the temperature of boiling sulphur and removing the products by a stream of carbon dioxide.

The author has extended the method to mixtures of calcium salts with very satisfactory results.

The conclusions arrived at are: (i) That the decomposition is not of one molecule, but of two. (ii) There is a greater tendency towards the production of the mixed than of the simple ketone. (iii) That, for economy, it is advisable to distil the more expensive salt with excess of the cheaper one. By so doing the yield of mixed ketone from a given weight of the expensive salt is increased.

88. "Isomeric additive products of methyl, ethyl, and propyl benzyl ketone with benzylidene aniline. Part IV." By F. E. Francis and E. B. Ludlam.

The benzylideneaniline additive products of methyl, ethyl, and propyl benzyl ketones were prepared in the expectation that they would furnish evidence as to the constitution of the tautomeric forms which such compounds are capable of assuming. Methyl benzyl ketone contains the group $CH_3 \cdot CO \cdot CH_2$–, which in ethyl acetoacetate gives rise to the tautomeric form $CH_3 \cdot C(OH)\colon CH$–, and it was hoped that the work would have contributed to the solution of the problem of the constitution of the tautomeric forms of that compound.

Methyl benzyl ketone gave with benzylideneaniline an additive product melting constantly at 173° (α). This, under the influence of piperidine, gave the β-modification melting at 182°, and another modi-

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CHAPTER III.

NON-METALLIC POISONS.

Phosphorus.

THERE are two kinds of phosphorus, the crystalline and the amorphous. The former is found in commerce as yellow, translucent, waxy-looking sticks, which are usually kept submerged in water to prevent oxidation. It is but slightly soluble in oil, alcohol, ether, naphtha, and other liquid solvents, but freely soluble in carbon disulphide, and chloroform. When exposed to the atmosphere, it gives off dense white fumes, composed, by union with the oxygen of the air, of phosphoric and phosphorous acids. The amorphous or allotropic form, invented by Schrötter, is made by exposing the ordinary crystalline form to a temperature of 240°–250° F., in its own atmosphere, for a period of 50–60 hours; but if heated to 260° F., it is reconverted into ordinary phosphorus. It is red in colour, quite opaque, and is not soluble in CS_2. It does not give off fumes in the air, nor does it become luminous in the dark as the other form, except when heated to a temperature of 200° F.

Poisoning from Phosphorus is infrequently homicidal,—a case was tried, however, at the Bodmin Autumn Assizes, 1857—but it is often taken accidentally and suicidally. It is obtained for suicidal purposes in rat-pastes, and in the heads of lucifer matches. One adult swallowed the heads of six packets of matches. Another, who died, drank the liquid in which fifteen boxes had been steeped.[1] The makers of lucifer matches, exposed to the fumes already mentioned, suffer from necrosis of the jaws and caries of the teeth, the necrosis being most apt to occur at points where the teeth are carious. This affection does not happen so often in the manufacture of "safety matches," since these are made of amorphous phosphorus. Stockman,[2] from experiments made on guinea-pigs, came to the conclusion that the fumes of phosphorus simply weakened the nutrition of bone and periosteum, and thus afforded a *nidus* for the tubercle bacillus, which produced the caries. This view, however, is not accepted by Oliver, one of the members of the Home Office Committee on the Use of Phosphorus in the Manufacture of Lucifer Matches. The Blue Book containing the Reports of this Committee must be studied by those who desire exhaustive information on the whole subject. According to Mr. Dearden,[3] *fragilitas ossium* is another effect of exposure to phosphorus fumes. He adduces statements of other observers in this direction, as well as observations of his own.

[1] *The Lancet*, vol. i. 1889, p. 912. [2] *B. M. J.*, vol. i. 1899, p. 9.
[3] Ibid., vol. ii. 1899, p. 270.

Symptoms.—When phosphorus—say in the form of rat-poison paste—is swallowed in a poisonous dose, pain quickly develops in the stomach, which may, however, not be marked, and is succeeded by vomiting. The person may complain of a garlic taste in the mouth, and a garlic odour may be perceived by an observer in the person's breath. Along with these there is an acrid, burning sensation in throat and gullet, accompanied by great thirst. The vomited matters are usually dark in colour—dark-green, coffee-coloured, or quite black,—have a garlicky odour, and, if exposed in the dark, become luminous or phosphorescent. If diarrhœa be present—for it is a variable feature in such cases—the fæces are likewise dark and luminous. The main signs of shock develop,—the pulse becomes small, irregular, feeble, and, at times, imperceptible, there is cold, clammy skin, anxious pinched face, and sub-normal temperature. Coma or convulsions usually precede death. In most cases, however, the progress is not continuous to a direct fatal termination; there is usually an intermission or lull in the severity of the symptoms, so much so, at times, as to give the impression that the worst is over. But sooner or later—it may be two or more days—a new set of symptoms appear, viz.: jaundice, which is a marked and notable appearance: the epigastric pain, not yet gone from the original attack, increases in severity, and the abdomen becomes distended. On examination the liver will be found enlarged, as probably also the spleen. Vomiting returns. Hæmorrhages may set in from the nose, or from other mucous surfaces, or (in addition, or alone) subcutaneous hæmorrhages—purpura—may appear. The urine becomes scanty, strongly acid in reaction, high-coloured, and contains blood, albumin, and bile-colouring matter. The nervous system becomes implicated—sleeplessness, pains in the head, etc., show themselves. Gradually, the patient gets weaker, the pulse becomes weaker, irregular, and more compressible, and some degree of hyperpyrexia sets in. The patient becomes apathetic, and thereafter appears coma or convulsions, which usually precedes death.

Grose[1] records a typical case from swallowing rat-paste, in a girl of three and a half years, death following on the fifth day. Post-mortem examination revealed enlargement of liver, which was in a state of acute fatty degeneration; and the heart and kidneys felt greasy on section. The urine passed during life reduced Fehling's solution.

Post-Mortem Appearances.—The appearances, generally, are those of a highly irritant poison, consisting of inflammation and erosion of mucous membrane of throat, gullet, stomach, and intestines, or it is completely destroyed in patches. The stomach may contain some dark-coloured, or bluish matter, which may have a garlicky odour, consisting of mucus and altered blood, and in addition, where rat-paste has been taken, of Prussian blue. The contents may give off white fumes on exposure to air, in which case they will be luminous in the dark. The liver is the seat of considerable disorganisation, being usually found in a softened condition and enlarged. Its colour varies. On microscopic examination, extensive destruction of liver cells is found, besides the presence of considerable quantities of fatty globules. Fatty degeneration of the muscular fibres of the heart, and also of voluntary muscular

[1] *The Lancet*, vol. ii. 1889, p. 902.

fibre is present. The blood of the body is of a dark appearance, is fluid in consistency, does not redden on exposure to air, and on microscopic examination, it is seen that the hæmoglobin is dissolved out of the stroma into the liquor sanguinis. The diagnosis of the liver conditions from phosphorus and of those in acute yellow atrophy have been the subject of much discussion. Some observers are of opinion that they are pathologically different as to their causation; others that they are closely allied. The former pin their faith upon the fact that in the liver condition due to phosphorus there is enlargement of the organ, and that on microscopic section the acini are distinctly visible, whereas in the other there is atrophy of the organ, and the acini have disappeared. This seems to be a question for the future yet to decide.

Fatal Dose.—The smallest recorded fatal dose is $1\frac{1}{2}$ grains; in another case 2 grains was the fatal dose. Both of these cases are quoted by Christison. Recovery, however, has followed doses of 4 and 6 grains.

Fatal Period.—Four hours (Orfila). The period, however, is usually longer, extending even into days.

Treatment.—Early use of the siphon-tube, and free lavage with warm water and "Sanitas," or rectified turpentine, or potassium permanganate. Evacuation of bowels with castor oil and small addition of turpentine. Thereafter, the most prominent symptoms must be treated.

Chemical Analysis.—Some dependence must be placed on the garlicky odour of vomited matter, fæces, and contents of stomach, and much importance should be attached to these giving off white fumes, and to their luminosity in the dark. In dealing with the contents of the stomach especially, careful search should be made, under water, for solid particles of a suspicious appearance—of phosphorus, or of Prussian blue. Thereafter, a portion of the contents should be shaken up in a separator with carbon disulphide, and after separation of the fluids, the disulphide is drawn off and allowed to spontaneously evaporate in a dark place, the observer keeping watch for any appearance of luminosity. Any phosphorus present will show as oily globules, which, on being touched with a red-hot wire, will burst into a bright yellow flame.

Mitscherlich's test or process, which is intended to detect small quantities of phosphorus, is carried out as follows: the suspected material is mixed with water acidulated with sulphuric acid; it is then transferred to a glass retort fitted with a long condenser, and to the tube from the retort is fitted an adapter which ends in a receiver containing a solution of silver nitrate. Distillation is conducted in the dark, luminosity in the tube being an evidence of the existence of the poison. This process will detect one part of phosphorus in 100,000 parts of material. Luminosity, however, may be prevented by the very substances used in the treatment of the case before death, as turpentine, ammonia, or alcohol, but even in that case the phosphorus will blacken the silver solution by reducing the silver to the metallic condition.

Dusart-Blondlot's test depends upon the combination of phosphorus

with nascent hydrogen and formation of phosphuretted hydrogen (PH_3). The gas is generated as in Marsh's process. It gives on ignition at a platinum jet a flame which is somewhat greenish in colour, particularly in its middle. Some of the gas may be passed into a silver nitrate solution, when a precipitate of Phosphate of Silver will form.

Scherer's test depends upon the reducing effect of phosphorus fumes on silver nitrate. If a portion of the suspected material be placed in Dowzard's apparatus for Gutzeit's test for arsenic, and lead acetate solution, to fix any H_2S which may be present, be placed in one or more of the cells, and the top of the apparatus be capped with paper moistened with silver nitrate—the whole being kept in the dark—the reaction will be obtained after some hours, even with minute quantities of phosphorus.

GASEOUS POISONS.

There are certain gaseous compounds of metallic and metalloid bodies which exert a poisonous action, and of some of them especially the toxic effects are rapidly produced and are very lethal. These gases of the metallic bodies are the hydrogen compounds of arsenic, antimony, and phosphorus, and of these, probably the most common is the first named; of the metalloid bodies, there are certain compounds of sulphur and of carbon, in addition to chlorine. Bromine and iodine in the form of vapour are also irrespirable and produce poisonous effects; so also is the vapour of hydrocyanic acid which, however, will be considered under the head of vegetable poisons.

We shall, therefore, divide this group into two sub-groups, viz.:—

I. The Gaseous Compounds of the Metals, including—
- (*a*) Arseniuretted Hydrogen,
- (*b*) Antimoniuretted Hydrogen,
- (*c*) Phosphuretted Hydrogen.

II. The Gaseous Compounds of the Metalloids, including—
- (*a*) Carbon gases.
- (*b*) Sulphur gases.
- (*c*) Chlorine.

I. Gaseous Compounds of Metals.

A. **Arseniuretted Hydrogen** (AsH_3).—This gas is formed in a variety of ways:—

(1) By solution of arsenides of the metals in water;

(2) By the action of dilute HCl or H_2SO_4 on alloys of Zinc, Copper, or Tin, or on ores which contain arsenic;

(3) By Marsh's test; (4) by dissolving, Zinc, Tin, or Iron, containing Arsenic Acid with dilute HCl or H_2SO_4(: $2AsH_3O_4 + 8Zn + 16HCl = 2AsH_3 + 8H_2O + 8ZnCl_2$); (5) by electrolysis of water containing Arsenious or Arsenic Acid; (6) by the growth of moulds in starch-paste put on wall-paper which contains arsenic.

It is a colourless gas, possessing a disagreeable odour of garlic, but does not redden litmus. It burns in the air with a bluish-white flame, forming water and arsenious acid.

Poisoning by this gas has arisen in a variety of industrial and scientific pursuits. Of 81 cases the records of which we have recently investigated, including two which came under our personal observation, the following is a classification of their origin :—

I. From chemical operations in laboratories :—		
(*a*) When the operator was dealing with known arseniferous substances	=	8
(*b*) Where the substances were not known to contain arsenic	=	10
II. Trade processes	=	56
III. Domestic environment	=	6
IV. Cause not known to writer	=	1
Total . . .	=	81

Poisonous results were produced from such laboratory experiments as the generation and inhalation of hydrogen to produce Tyndall's experiment of the altered "timbre" of the voice, the demonstration of Marsh's test to students, the intentional generation of the gas for experimental purposes, and testing for arsenic by Marsh's test in the bodily organs of a girl poisoned by arsenic; also from such trade processes as the following: researches in, or manufacture of, anilin colours; filling of balloons with hydrogen; extraction and treatment of ores; manufacture of zinc chloride; utilisation of galvanisers' zinc flux skimmings, the manufacture of bleaching-powders, and others.

Symptoms are as follow: (*a*) an indefinable feeling of illness and great weakness; (*b*) giddiness; (*c*) faintness; (*d*) pains in head and epigastrium; (*e*) coldness of the body; (*f*) sense of oppression of breathing, with, perhaps, some cyanosis; (*g*) nausea, sickness, and vomiting. These are quickly followed by :—(*a*) continuous vomiting of bilious matters, and, very often, of blood; (*b*) jaundice, which may vary in tint from golden-yellow to mahogany, ranging through coppery, bronze, and mulatto tints; (*c*) thirst and dryness in throat, with weakness of voice; (*d*) pains in loins; (*e*) pains or sense of fulness over region of liver; (*f*) hæmorrhages from one or more different parts of the body; (*g*) hæmoglobinuria or hæmaturia, oliguria, or, it may be, complete anuria; (*h*) usually clear intellect, but generally before death, coma or delirium; (*i*) subnormal temperature; (*j*) hiccough.

Post-Mortem Appearances.—First, so-called jaundice, which is found not only on skin and conjunctivæ, but also in internal organs; in certain cases, a blue line on the gums has been seen. There is little abnormal change in the brain. The lungs have been found collapsed and congested. In the pericardium and pleuræ reddish or reddish-brown coloured serum may be found. In the heart, ante- and post-mortem clots are commonly found. The liver is more or less enlarged, and the gall-bladder distended with bile. The colour of the liver is often abnormal; ranging from a simple yellow to a deep indigo colour. The kidneys are also changed in colour, from dark-red to indigo, and they are also enlarged. The spleen is frequently also enlarged and altered in colour. In the stomach there is congestion of the mucous membrane, sub-mucous petechial hæmorrhages,

and patches of erosion ; in which changes the intestines often share. Microscopic examination of the blood reveals solution of the hæmoglobin from the corpuscles into the liquor sanguinis, "shadows" of red corpuscles, and destruction of the red discs. Fatty degenerative changes are found in muscle-fibre of heart, and in tissues of liver and kidney. The urine contains hæmoglobin, débris of red blood discs, granular matter, exudation cells, red-blood corpuscles, tube-casts, fatty, hyaline, bloody, and amorphous urates or phosphates. Bile-pigment may also be found, but no bile-acids. Further microscopic examination of the blood will show the additional following changes, viz. : (1) considerable reduction in number of red corpuscles per cubic millimetre ; (2) reduction in hæmoglobin-value of blood ; (3) alteration in shape and colour of red corpuscles. The blood-spectrum is, sometimes, that of met-hæmoglobin.

Fatal Quantity.—Very small. The mere act of sniffing the gas has produced serious symptoms, so that a very small quantity of it is toxic.

Fatal Period.—Usually about five days after inhalations.

Treatment.—Inhalations of oxygen. We believe that bleeding, followed by transfusion of blood, would be of the highest value. Baths or hot packs are of great service in stimulating excretion by the skin. Other treatment must follow lines indicated by individual cases.

Antimoniuretted Hydrogen (SbH_3).—This gas is not so toxic in its effects as the hydrogen gas of arsenic, and we are not aware of any published case of fatal poisoning from it alone. In the treatment of ores, however, there can be little doubt that from those which contain both arsenic and antimony, the same operation which will liberate the one will also free the other. This took place in Llanelly on one occasion, and death resulted.[1]

Phosphuretted Hydrogen (PH_3).—The only cases with which we are acquainted, and in which a fatal accident resulted, arose during the progress of a chemical experiment.[2] A young chemist, shortly after making experiments with this gas on a fairly large scale, was seized with symptoms of poisoning from the effects of which he died. The other case is recorded by Bremner.[3] By reason of the former case, a series of experiments as to the effects of this gas upon animals was instituted by Henderson (*loc. cit.*). When a rat was exposed to an atmosphere containing one per cent. of the gas, death resulted within half-an-hour ; a second, the atmosphere containing only ·2 per cent., died in 33 minutes ; and a third, where the gas only amounted to 1 in about 5000 of air, died within 24 hours. In another experiment made by subjecting a rat to spontaneously inflammable PH_3 generated by the action of impure phosphide of calcium on water, a fatal result also ensued. The symptoms observed in these animals were, chiefly, (*a*) great irritation of the skin, (*b*) rapid breathing at first, and, later, slow and laboured respiration, and (*c*) convulsions. The post-mortem appearances were : (*a*) anæmia of brain, (*b*) engorgement of lungs, liver, and brain membranes with dark venous blood,

1 "Public Health," vol. iv. 1892, p. 317.
2 Henderson and Clark, *Proc. Phil. Soc. of Glasg.*, vol. xi. p. 517.
3 "Syd. Soc. Biennial Retrospect," 1865–66, p. 443.

and (*c*) engorgement of heart with dark-coloured blood. The presence of phosphorus in the organs of the animals was detected by Marsh's test, a green tongue being visible in the hydrogen flame, confirmed to be phosphorus by the spectroscope.

Hydrofluoric Acid.—The gaseous acid which is used for the purpose of etching is poisonous in its action, producing corrosion of the skin and, later, painful ulcers which are difficult to heal. King records[1] the case of an adult who swallowed about half an ounce of the liquid preparation, and who died in 35 minutes thereafter. The chief symptoms were violent pain in the mouth, throat, œsophagus and stomach, and severe vomiting. The post-mortem appearances consisted of corrosion of the parts with which the poison came in contact; the mucous membrane of mouth, and that of the œsophagus, were in patches whitened in appearance and denuded of epithelium, while that of the stomach was blackened, the organ itself containing a blackish fluid. Sir Charles Cameron has recorded a case which indicates poisoning by the gaseous form of silicon fluoride, in a young man who was employed in the manufacture of superphosphate of lime for manurial purposes. In the process the crude phosphate is subjected to the action of sulphuric acid, and during the operation such gases as carbon dioxide, nitrogen oxides, fluoric acids and fluoride of silicon are evolved. An analysis of the lungs of the deceased showed that one entire organ contained at least 0·75 gramme of silica (SiO_2), and of the crude phosphate used in the works that it contained 6·36 per cent. of calcium fluoride. He carried out a series of experiments upon animals to investigate the toxicity of the fluoride of silicon, and demonstrated that exposure to an atmosphere containing 0·5 per cent. killed a guinea-pig within half-an-hour, and to one containing 2 per cent. within four minutes.

II. Gaseous Compounds of the Metalloids.

A. Carbon Gases.—It may be said generally, that whatever carbon gas or mixture of gases takes the place of the air which is breathed to an amount that substantially reduces or supplants oxygen, places life in peril. The gases which, however, specially prove toxic in their effects, are Carbon Monoxide and Carbon Dioxide, of which some detailed consideration is necessary.

Carbon Monoxide.—The sources of carbon monoxide gas are various. Among the principal are the resultant gases from ignition of explosives, the slow combustion of "blaise" or iron-waste heaps, coal-gas itself, and coal-gas admixed artificially with variable proportions of "water-gas," the use of "geysers" in bath-rooms, lime-kiln burning and the air of mines. As exemplifying the former, the Crarae disaster at the quarries of that name on Loch Fyne may be cited, wherein several citizens of Glasgow, who rushed into the quarry to witness the effects of the explosion of some tons of gunpowder, fell as if shot dead, and of whom some did actually die. They had walked into an invisible atmospheric lake of CO_2 and CO gases. Most high explosives yield this latter gas in poisonous quantities, as dynamite, gun-cotton, nitro-glycerine, tonite, roburite, sicherheit, and others, especially when the explosions have occurred in confined spaces,

[1] *The Lancet*, vol. i. 1873, p. 203.

as mines. In the manufacture of roburite, which is composed of dinitro-benzene, chloro-nitro-benzene, and ammonium nitrate, danger occurs to the workmen in cleaning out the flues. The operation is so dangerous, that although the men are each provided with a special suit of clothes and respirator for the purpose, they are only permitted to work for three minutes at a time in the flue, and are bound to remain out for twenty.[1] So dangerous and injurious to health did it prove in the experience of workmen, that in certain works where it was used as an explosive, the men refused to work if its use were continued; consequently a Committee of Inquiry, composed of Prof. Dixon, Dr. Mouncey, and Mr. Hannah, was appointed to investigate its effects. This Committee reported that when roburite is fired in a coal mine, a recognisable quantity of CO is given off, but if in a boiler, no CO can be detected. They therefore recommended that, when it was used in mines, the products of combustion should be rapidly diluted with large quantities of fresh air.[2] Sicherheit (the German word for "security") is also chiefly composed of dinitro-benzene ($C_6H_4(NO_2)_2$), and its manufacture is attended with danger. The symptoms of poisoning are almost identical with those from roburite, consisting of unconsciousness, cyanosis of face, lips, and finger-tips, weak, irregular pulse, and general collapse. Particulars of individual cases of poisoning may be studied in the following references.[3]

From the second above-named cause, we have seen two deaths result. Within a fortnight of one another, two tramps lay down on the bank of a smouldering "blaise-heap," for the purpose of warmth, and were found dead in the morning, with marks of burning upon those parts of their bodies which were in contact with the ground.

From coal-gas, we have seen several cases of poisoning. Perhaps the most notable example was that in which in January, 1895, we were called upon to examine the bodies of members of a family under the following circumstances. By reason of the fact that the occupants of a cellar-dwelling were not astir in the morning, and from the oppressive odour of coal-gas which was perceived in the passage leading to the house, it was feared that some grave mischief had happened to the father, mother, and four children, who inhabited the apartment. Consequently, the door was forced by the police. When we entered the room a few minutes thereafter, the mother and children were found to be dead, and the father to be deeply comatose but still living. An interesting fact, worthy of note, was observed: a paraffin oil-lamp, which stood on a low shelf near the fire-place, was found to be burning freely, and the flame gave no indications that it was not receiving sufficient oxygen for efficient combustion.[4] No gas was used in the house. On examination later, it was found that a gas-supply main—one and a half inches in diameter—had burst in the ground outside of the dwelling, and that the issuing

[1] *The Lancet*, vol. ii. 1889, p. 81.
[2] Ibid., vol. i. 1889, p. 1100; idem, vol. ii. 1889, p. 124; *Manchest. Med. Chron.*, May 1889.
[3] *B. M. J.*, vol. ii. 1889, p. 127; idem, vol. ii. 1889, p. 244; *The Lancet*, vol. ii. 1889, p. 368.
[4] See a similar case, *B. M. J.*, vol. ii. 1896, p. 1443.

gas had found its way into the apartment through the foundations of the building and the flooring. Altogether, we have seen fifteen to eighteen cases of coal-gas poisoning, which, however, with the exception of the six cases above narrated—for the father also died—made good recoveries, although in several instances the persons were deeply comatose.

Pettenkofer in a communication to the journal, *Nord und Süd*,[1] gives several illustrations of the poisonous effects of coal-gas entering dwellings from street main-pipes. Out of twenty-two instances recorded in Munich, twenty occurred in the winter months, and Pettenkofer's explanation of this is that the heated houses in winter act like so many cupping-glasses on the air of the soil. In one of the instances mentioned, two persons were found dead, and one living but insensible who afterwards died, a canary was found dead in its cage, and a dog lay senseless on the floor, from the effects of the gas which had entered the house from a leak in a pipe in the street 35 feet from the wall of the house. In some of the other cases, however, he points out that the source of the leakage was as much as 100 feet from the affected dwelling. At Glossop, in 1884, four deaths occurred in a house from the same cause.[2]

The practice of municipal corporations in permitting the admixture of water-gas with coal-gas cannot be looked upon as otherwise than a dangerous one to the gas consumers. In Belfast, Liverpool, Edinburgh, and other large cities, this practice prevails, but it is not followed in Glasgow. This water-gas, or producer-gas, is made by passing air and steam through incandescent coke or other carbonaceous fuel, at a temperature of about 2000° F., whereby the oxygen of the air and steam unites with the carbon from the fuel to form a gaseous mixture, of which CO is one of the principal ingredients, forming about 47 per cent. According to Cayzer,[3] who has collated the reports of the Lighting Commissioners of various American cities in the State of Massachusetts, during 1896 there were 76 cases of escaping gas, from which 51 persons died and 118 others were injuriously affected; the gas used being carburetted water-gas, which is made by passing water-gas over a large surface of material charged with vaporised oils containing hydrocarbons. In the same State in 1897, 60 persons died and 74 were injured. In Liverpool, Birmingham, Stockport, Leeds,[4] and other places, deaths from this gas have also happened. It is stated, as the result of inquiry,[5] that in a certain district of Liverpool, the night supply of gas contained 17 per cent. of carbon monoxide. Coal-gas normally contains from 6 to 9 per cent. of CO, but when water-gas, or carburetted water-gas is mixed with coal-gas, the proportion of CO rises much higher, depending upon the ratio of admixture. Carbon monoxide is an odourless gas, but when mixed with olefiant gas the odour of the latter is always perceptible. Coal-gas poisoning may result from ignorant persons blowing out the gas-

1 Jan. 1884; *B. M. J.*, vol. i. 1884, p. 822.
2 *B. M. J.*, vol. i. 1884, p. 121.
3 "Carburetted Water-Gas and Carbon Monoxide Poisoning."
4 *The Lancet*, vol. ii. 1889, p. 1358.
5 *Public Health Engineer*, April 1901, p. 289.

light, from over-turning an unchecked tap, from the accidental fracture of a gas-supply pipe, and in a variety of other ways.[1] A considerable number of deaths has been caused by the use of gas "geysers," or so-called "instantaneous heaters" in bath-rooms, in the use of which much CO is generated. Such cases are frequently recorded.[2]

As the result of lime-burning, deaths from this gas are also common. A unique case of this kind which came under our observation is as follows. In an inhabited street in Glasgow is a lime-burning work consisting of three kilns, one of which abutted closely—within some inches—on the gable-end of a newly-built tenement property of two flats, occupied by different families. During the night of November 30, 1899, the members of the family living in the ground-floor apartments next this gable were seized with faintness, sickness, and vomiting, which they attributed to a disagreeable pungent smell in the house. They took refuge in the house of a neighbour. By next day they were comparatively well. Their neighbours on the flat above, however, had not been seen since the night before, and vigorous rapping at the door elicited no response. Fearing some mishap, the police entered by the window, when it was found that a woman and her two children were lying dead in the bed of the back apartment, and a man, who was occupying the bed in the front apartment, was deeply unconscious but still living. He was at once removed to the Infirmary, where he was treated; it was only, however, after he had been freely bled that he showed signs of improvement. He recovered. We made a post-mortem examination of the dead bodies the day after.

Haldane's "Report on the Causes of Death in Colliery Explosions and Underground Fires" (1896), the Report of Professor Le Neve Foster on the Snaefell mining disaster, and other like documents, show how common is this cause of death in mines and collieries. The source of the CO in the Snaefell case was burning timber, in which combustion was not active because of imperfect supply of air due to falling-in of the roof through the burning of the wood-supports; in the Whitwick Colliery disaster in April, 1898, fire in the pit was also the cause. Choke-damp, which is a mixture of CO and CO_2, may, however, be present in mines from other causes than fire; indeed, it is liable to form in all collieries, but in some more than others, at "dead-ends," where the ventilation is imperfect. In fires in buildings, the CO in smoke is, doubtless, the cause of a certain number of deaths of persons.

Another source of this poisoning is in ironworks flues connected with the processes for saving ammonia and other valuable bye-products. Dr. Scott has recorded[3] the case of a man who was found insensible at the front of one of the flues connected with the above process at the Clyde Ironworks near Glasgow, and the notes of a

[1] *B. M. J.*, vol. i. 1899, p. 780; idem, vol. i. 1898, p. 858; idem, vol. ii. 1897, p. 1772.
[2] *The Lancet*, vol. ii. 1889, p. 710.
[3] Ibid., Jan. 25, 1896.

N. [illegible] - Carbonyl Cowan, J. Ent. Soc. Vol I, 1903, p. 214.

second case which happened at Coltness Ironworks. In April, 1901, we made a post-mortem examination of the body of a vigorous man who was found dead in a boiler which he had been sent to repair, and his body bore unmistakable evidence of death from this gas.

Dangerous effects may also result from heating domestic apartments by coke-stoves; and the use of flueless charcoal braziers is a source of many deaths, by accident or suicide, especially in France. These effects may also be produced in unlooked-for ways. Carbonic oxide forms with Nickel a compound $Ni(CO)_4$ which is a clear liquid of considerable refractive power, of a sp. gr. of 1·3185 at 17° C., and which is soluble in alcohol, benzene, chloroform, and olive oil. It evaporates on exposure to the air. M'Kendrick and Snodgrass[1] have investigated its physiological action. They have demonstrated that it is highly toxic not only when injected into the body but also when inhaled as a constituent of the atmosphere. From a series of experiments they proved that the vapour of this substance when present in the air to the extent of less than 0·5 per cent. was dangerous to life.

Symptoms.—The symptoms of coal-gas poisoning are as follow: deep coma, weak fluttering pulse, heavy breathing, with puffy or blowing expiration; contraction of pupils, which do not respond to stimuli; cyanosis of face; lividity of lips, with froth at mouth; sub-normal temperature; and coldness of body. Those of carbon-monoxide poisoning differ in some measure. They are as follow: deep coma; pallor of face; eyes staring and glassy, pupils being dilated and fixed; froth at mouth; breathing shallow and quiet; pulse weak, almost imperceptible; sub-normal temperature; coldness of body. Should the person recover from the severe symptoms of CO poisoning, it may take months before he is restored to his former health, or he may never quite recover. Dr. Scott in the case already recorded, states that the man whose case he describes suffered from *dementia* for months after, which he ascribes to the effect of the blood-poisoning from this gas; and in the Coltness case, the patient was maniacal for three days, insensible for eight, and his vision was imperfect for seventeen days. Even at the end of two years, although his bodily health had been fairly restored, he still remained facile in mind, and could not be trusted with any responsible work. In certain circumstances of occupation or otherwise, persons may be exposed to the repeated inhalations of small amounts of CO gas. From these, sooner or later, pernicious effects follow, such as: anæmia, malnutrition, headache, neuralgia, symptoms resembling peripheral neuritis, and, it may be, mental disturbances, such as those already indicated.

Post-Mortem Appearances.—In the cases which we have examined from coal-gas poisoning, where there is no admixture with water-gas, or carburetted water-gas, the signs were mainly these: the blood of the body generally is dark and fluid. The internal signs, in short, are those of asphyxia.

In Carbon Monoxide Poisoning.—There is a rosy or pink coloration of the skin of the body on face, neck, shoulders, breast, and front and back of thighs, and the same rosy colour is present on the

[1] *Proc. Phil. Soc. Glasg.*, vol. xxii. p. 204.

dependent parts of the body instead of the usual livid colour, but the tint is not so bright as on the anterior aspect of the body; the blood of the body generally is of a bright cherry-red colour; there is likely to be some measure of congestion of bases of lungs, and clear-coloured froth in the windpipe. If the blood be examined spectroscopically it will be found that the spectrum consists of two bands between D and E, which, however, are nearer the violet end than those of oxyhæmoglobin, which occupy a nearly like position (*vide* Fig. 71). This gas forms with hæmoglobin a stable compound called Carboxyhæmoglobin, on the formation of which the oxygen-absorbing and carrying property of the red corpuscles is weakened or destroyed. The physical appearance of the blood varies as is the percentage amount of CO in the air which is inhaled and the time of exposure and inhalation. In like manner, the spectroscopic appearances vary; in certain cases, instead of two bands appearing after the addition of a reducing agent, a single broad band of reduced hæmoglobin may be seen. Moreover, although the proximate fatal factor in ordinary coal-gas cases is the contained CO, which will, probably, be found spectroscopically, the rosy coloured markings on the body are not likely to be found, since the unconsciousness and symptoms of asphyxia are produced from the combined gases which compose olefiant gas. In order to detect the presence of CO in blood, the easiest and best method is as follows: dilute a drop of blood from the finger with water in a watch-glass or test-tube, until the solution appears yellow; take next a drop of the suspected blood and dilute it exactly in the same degree. If CO be present, the latter will remain distinctly pink, compared with the normal blood which will be a faint yellow. Let each now be examined by the spectroscope; probably in each case, two bands will be seen between D and E; now add a drop of NH_4HS to each test-tube, and again examine with the spectroscope, when it will be found that the normal blood spectrum of oxy-hæmoglobin will have disappeared, and instead of two bands, there will now be only one band of reduced hæmoglobin, while the spectrum of the other remains unchanged. There are certain chemical tests which may be applied to blood to detect the presence of CO, but they do not compare in absolute reliability with the spectroscope. They are, however, as follow: (*a*) Hoppe-Seyler's test, which consists in adding sodium hydrate (sp. gr. 1·34) to the blood. If CO be present, a bright red colour develops; if the blood be normal, a dirty green colour; (*b*) Kunkel's test consists in adding to the blood, which is diluted with nine parts of water, a few drops of a 3 per cent. aqueous solution of tannin; in the presence of CO a pinkish-white precipitate forms; if the blood be normal, a brownish-white.

Of the various methods for estimating quantitatively the percentage degree of saturation of the blood with CO, perhaps that of Haldane [1] is the easiest of application. It is a purely colorimetric method, and depends upon the colour of the blood under inspection relative to that of an equal quantity of blood saturated with CO. A one per cent. solution of the blood to be examined is put into a tube; into a second like tube is placed a solution of normal blood of like strength; and into a third, a solution of blood of like strength, but saturated with

[1] *Jour. of Physiol.*, 1895, vol. xviii. p. 430.

CO gas. The testing solution to bring up the colour is a standard solution of carmine.

The solution of carmine is made by mixing one gramme of pure carmine with a few drops of ammonia in a mortar, and dissolving, thereafter, in 100 c.c. of glycerine. The *standard* solution is made from the above by diluting 5 c.c. of the original solution to 500 c.c. with distilled water. When about 6 c.c. of this standard solution are added to 5 c.c. of ox blood diluted so that the mixture with water contains one per cent. of blood, the colour or tint formed will be equal to that of blood similarly diluted but saturated with CO gas.[1]

The blood under inspection is first compared with that of normal blood, and if it be brighter in tint the presence of CO is indicated in a certain unknown proportion. Then the blood under examination is compared with that of the sample saturated with CO, and if it be less bright than the latter, to it is added the carmine solution until the colours are alike, the amount added being noted. From the figures so obtained, the degree of saturation of the blood-sample under inspection is ascertained. Assuming that the carmine solution used is of such exact strength that 6 c.c. added to a one per cent. solution of normal blood will exactly produce a similar tint in quality and intensity to that of a one per cent. solution of blood saturated with CO gas, the calculation of percentage saturation of any given sample of blood under examination may be arrived at in one of two ways, viz.: (1) either by adding the standard carmine solution to the normal blood till the tint equals that of the blood-sample, or (2) by adding the carmine solution to the blood-sample until the tint produced is equal to that of the blood saturated with CO gas. Suppose that the former method be adopted, and that 1·5 c.c. of carmine solution are needed to bring up the sample of diluted normal blood to the tint of the diluted blood under inspection, then $\frac{100 \times 1\cdot5}{6} = 25$ per cent.; in other words, the hæmoglobin has taken up CO to the extent of 25 per cent. If the latter method be adopted with the same sample, and it be found that 4·5 c.c. of carmine solution are needed to bring up the tint of the suspected blood to that of the CO-saturated sample, then $\frac{100 \times 4\cdot5}{6} = 75$ per cent. Therefore $100 - 75 = 25$ per cent., the extent to which the hæmoglobin of the blood-sample is already tinted with CO.

Treatment.—In coal-gas poisoning, the patient must at once be removed to the open air where the air is in motion. If the body be cold, as is likely, it should be well wrapped in clothing after warming-pans or bottles have been applied. Artificial respiration will only be necessary if voluntary breathing be embarrassed or irregular. Inhalations of oxygen should be given. If in spite of these measures no sign of recovery appears, bleeding and transfusion of live human blood should be carried out. Farrah, in a paper read before the Philadelphia Pathological Society, November 1899, found experimentally on dogs that transfusion gave good results, the transfused blood being obtained from the carotid artery of a healthy dog and allowed to pass into the jugular vein of a dog almost lifeless from the gas, while saline

[1] Haldane, *op. cit.* p. 465.

solutions were only of temporary value, and hydrogen peroxide injected subcutaneously and intravenously yielded no beneficial effect. In carbon-monoxide poisoning, removal into the open air is not so urgently called for, although plenty of fresh air is necessary. The difficulty here is to obtain dissociation of the CO from the hæmoglobin, even by the administration of oxygen, because of the diminished capacity of the red corpuscles to absorb and carry oxygen. While artificial respiration, oxygen inhalations, and measures for the restoration of body-heat should be persevered in until, at least, the animal heat is restored, should no further improvement be manifested, bleeding and transfusion should be resorted to. It was only when this course was adopted in the Infirmary in one of our cases that sensible improvement set in.[1] Stimulants administered hypodermically, or *per rectum*, will also prove of service.

Carbon Dioxide (CO_2).—This gas, as has been pointed out, is often associated with Carbon monoxide, as in choke-damp, lime-burning, and brick-burning. It is the cause of fatal results in such occupations as well-sinking and well-cleaning, in breweries, in fermentation vats, and in aërated-water factories. In such circumstances, where it exists in large percentages, it quickly produces powerlessness and insensibility, and death; in lesser percentages, it produces a somnolent tendency and lassitude, and should the person yield to these influences, it endangers life by preventing the excretion of CO_2 from the lungs. If an animal be exposed to an atmosphere of CO_2, and, when death has resulted, if the blood of the heart be at once examined, spectroscopic investigation will reveal the formation of a compound of CO_2 with the hæmoglobin, which, however, is of transient existence. Should the blood of the animal not be examined till some hours after, the spectrum will be that of oxy-hæmoglobin. Constant exposure to the air of ill-ventilated apartments produces anæmia, mal-nutrition, and other symptoms.

Treatment.—Fresh air; artificial respiration; oxygen inhalations; restoration of bodily heat.

Acetylene (C_2H_2), which is a gas of unpleasant, pungent odour, and one of the sources of which is a "clogged" Bunsen burner, exerts prejudicial effects upon the body. The very common use of gas stoves for cooking and heating purposes demands that attention be paid to it. It is now used also for illuminating purposes, being generated by the action of water upon calcium carbide. There is no recorded case of acute fatal poisoning in the human subject, but there can be little doubt that regular exposure to an atmosphere in which even small percentage amounts of it are present is inimical to health, producing anæmia, malaise, mal-nutrition, and certain ill-defined nervous symptoms.

As a connecting link between the carbon and sulphur gases, we may next consider—

Carbon Bisulphide.—This gas, or rather vapour (CS_2), has but rarely given rise to fatal poisoning in the acute form, but chronic poisoning is not infrequently found in those employed in occupations in which it is used, as in india-rubber and gutta-percha works. Acute poisoning

[1] See also a case treated in Berlin by Prof. Leyden. *The Lancet*, vol. i. 1889, p. 51.

is usually due to swallowing the liquid, and chronic poisoning to exposure to the vapour or gas in the "curing-rooms" of rubber and gutta-percha factories.

Symptoms.—The symptoms in the acute form are: (1) unconsciousness; (2) dilated and fixed pupils; (3) embarrassment of breathing, with cyanosis of lips; (4) general symptoms of shock, due to absorption of the liquid; (5) odour of CS_2 in breath.[1]

The symptoms in the chronic form are very well described in a case by Edge.[2] This patient enjoyed good health until he entered the employment of a rubber factory. He had been a total abstainer for sixteen years previously. Soon after beginning work—which was in the "curing-room," where the fumes of CS_2 are given off largely from the goods in process of manufacture—he suffered from headache, giddiness, and drowsiness, dryness of tongue, and a constant taste of the stuff in his mouth. These symptoms disappeared a few weeks later, as he became accustomed to his environment. But the headache returned, accompanied by delirium and delusions of sight, and by frequent attacks of giddiness. His legs became weak and numb, and ultimately, before he went to hospital, he could neither walk nor stand without support; in short, he had the marked symptoms of peripheral neuritis. After treatment he recovered. In other cases, however, the same nervous symptoms present themselves in the upper extremities.[3] In addition to the foregoing symptoms, vomiting and abdominal colic may be found in certain cases.[4]

Post-Mortem Appearances.—These are mainly comprised as follows: (*a*) odour of CS_2 in internal cavities of body, especially in the abdominal, and marked presence of odour in stomach; (*b*) congestion of lungs and other organs; (*c*) markedly dark colour of blood of body; (*d*) congestion of walls of stomach, and punctiform hæmorrhages into mucous membrane.

Fatal Dose.—About half an ounce.

Fatal Period.—In a few hours. The above dose killed in $2\frac{1}{4}$ hours.

Treatment. — Siphon-tube and free lavage of stomach, until returning fluid ceases to be odorous; stimulants hypodermically, or *per rectum;* restoration of bodily warmth; artificial respiration, if required.

Chemical Analysis.—The poison may be detected by distillation of contents of stomach. It may, thereafter, be precipitated by a soluble salt of lead, as the sulphide of that metal. Its odour is an excellent guide to its presence.

SULPHUR GASES.

The principal irrespirable gases of Sulphur are the Dioxide and Hydrogen Sulphide, the former because of its extremely pungent character, and its consequent irritant action upon the mucous membrane of the respiratory tract, and the latter chiefly because of its lethal action upon the blood after absorption. Sulphuretted hydrogen

[1] See cases recorded by Davidson, *Med. Times and Gaz.*, 1878; and by Foreman, *The Lancet*, 1886.
[2] *The Lancet*, vol. ii. 1889, p. 1167.
[3] *Med. Chron.*, June 1887; *L'Union Médicale*, Sept. 1886.
[4] *Edin. Med. Jour.*, 1884 (Bruce).

poisoning is recorded mainly of workmen employed in chemical works,[1] and in connection with sewers. Fatal accidents from the latter cause have been recorded as occurring in London, Belfast, Glasgow, and other towns. In London, four men lost their lives, in Belfast, two died and two recovered, and in the Glasgow case (1901), one died. While sewer gas is a mixture of several gases, H_2S is undoubtedly the most lethal. Even in small percentages, it causes prejudice to the health of those exposed constantly to it. In amounts of 0·05 per cent. according to Lehmann's experiments[2] it produces alarming symptoms, and of 0·2 per cent., fatal effects upon animals.

Symptoms. — These are chiefly unconsciousness, cyanosis, and, generally, those of asphyxia due to stimulation of the vagus nerve, direct irritant action upon the alveolar mucous membrane of the lungs, and the combination of sulphur in the gaseous form with the hæmoglobin of the blood. This sulph-hæmoglobin is a comparatively stable compound, and may be detected in the blood of those poisoned by this gas by the following spectrum, viz.: Two bands as in oxy-hæmoglobin, with the addition of a third narrow band in the red, between C and D, which does not disappear when a reducing agent is added. At the same time, it cannot be detected in the blood in every case of H_2S poisoning.

Post-Mortem Appearances.—These may be considered as those of death by asphyxia; but the blood has a darker hue than in ordinary cases from this cause. On examination of the blood, a spectrum will perhaps be found which, at first sight, looks like that of met-hæmoglobin, viz.: two bands as in oxy-hæmoglobin with a third narrow band between C and D toward the red end of the spectrum. It is, however, distinguishable from that of met-hæmoglobin by the fact that this third band does not disappear after addition of a reducing agent to the sulph-hæmoglobin, but does disappear in that of met-hæmoglobin.

Fatal Quantity.—Not well ascertained.

Fatal Period.—From some minutes to hours.

Treatment.—Removal to fresh, moving air; artificial respiration; oxygen inhalations; restoration of bodily warmth; and stimulants. The recommendation proposed by some to give inhalations of chlorine is, to our mind, so dangerous on the ground of the likelihood of its increasing the irritation of the already irritated respiratory mucous membrane, that it should on no account be tried.

Chemical Analysis.—The presence of this gas in the stomach and tissues may be detected by the addition to the filtrate of a soluble lead salt; but this when found in small quantity may only be the result of decomposition. The discovery of the spectrum of Sulph-hæmoglobin is far better proof of its presence in the body, since it shows that the gas must have been exhibited during life.

Chlorine, Bromine, and Iodine.

These three substances in the gaseous or vaporous form exert a highly irritant action upon the respiratory mucous membrane, characterised by violent, convulsive coughing of an irrepressible kind, and dyspnœa, which are followed

[1] *B. M. J.*, 1892. [2] *Arch. für Hygiene*, 1892.

by bronchitis or pneumonia. Chlorine inhalation is not an uncommon occurrence in chemical workers engaged in the manufacture of hydrochloric acid and bleaching-powder, but fatal results even from such occupations are very rare, and when they do happen are more likely to be due to the local inflammatory lung mischief than to any constitutional effect of the gas.[1] The chronic effects of exposure to an atmosphere containing chlorine soon become apparent on workmen. They become anæmic, lose flesh, and their teeth rapidly decay. Sooner or later, also, they develop lung complaints, which ultimately take the form of chronic bronchitis and emphysema; and, in addition, dyspepsia, which is not altogether due to this gas, but to the irregularity of their lives consequent upon day and night shifts of work. Sir Charles Cameron records a case in which a sailor died from having slept in a cabin containing a quantity of chloride of lime. Before death he was comatose. During the post-mortem examination of the body a marked odour of chlorine was given off when the ventricles of the brain were opened.[2]

Following upon this case, Binz of Bonn experimented upon rabbits, and showed that chlorine, as well as bromine and iodine, paralysed the nerve centres, and that the proximate cause of death was asphyxia.

Treatment. — In men who have been "gassed" by this substance, removal from the works is the first consideration, and thereafter confinement to bed, with treatment of lung sequelæ.

Fatal Quantity.—Not certain.

Fatal Period.—In the case mentioned in the first reference, the patient died at the end of 48 hours.

FIG. 104.—Case of Anthracoid Acne from internal administration of Potassium Bromide. This illustration was kindly lent to the author by Professor Hall, University College, Sheffield.

BROMINE.—This substance both in the liquid and vaporous form has caused death. Internally, when taken as the fluid, it acts corrosively, and when inhaled, as an irritant upon the respiratory membrane. The compounds of bromine with ammonium, sodium, and potassium act as sedatives upon the nervous system, and in overdoses, produce unconsciousness and signs of collapse, and put life in jeopardy. Dr. Dougall has recorded a case in which a patient took one ounce of potassium bromide one night, and half an ounce the following night. When admitted to hospital, he was unconscious, his face was livid, his extremities cold and blue, and his temperature 96·8° F. It was only after two weeks' treatment that symptoms of improvement manifested themselves.[3] Where liquid bromine has been taken, unconsciousness and collapse quickly supervene. Skin eruptions of different characters are occasionally produced from the internal administration of potassium bromide. (Fig. 104.)

Post-Mortem Appearances.—In the case where liquid bromine has been taken,

[1] *Vierteljahrssch. f. ger. Med.*, 1888: *Dub. Quart. Jour. of Med. Sc.*, 1870.
[2] *Dublin Journ. of Mental Science*, Feb. 1870.
[3] *Glasg. Med. Jour.*, 1893.

there will be inflammation of gullet and stomach, with extravasations of blood into the mucous membrane, which, generally, presents a very dark, leathery appearance. When the substance has been inhaled, the burden of its action will have fallen upon the respiratory tract, and will be indicated by bronchitis or pneumonia.

IODINE.—Liquid preparations of Iodine—such as the liniment or tincture—have been used for suicidal purposes, and cause corrosion of the parts with which they come in contact in swallowing, and also of the stomach. Its vapour is very irritant on the respiratory tract. Its potassium salt, which is now largely used in medicine, has given rise upon occasion to dangerous symptoms; but in the cases recorded, its exaggerated action—because the doses were not exceptionally large—must be considered as the effects of the patients' idiosyncrasy.

Symptoms.—In the liquid forms, when swallowed, the symptoms are those of a corrosive and irritant poison, viz.: swelling of mucous membrane of mouth, throat, gullet, and stomach, accompanied by dark-brown, or yellowish staining of parts; intense, burning pain in mouth, gullet, and stomach; vomiting; and, generally, signs of shock.

Post-Mortem Appearances.—Are indicative of corrosive action by a brownish or yellowish substance.

Fatal Dose.—One drachm of the tincture has killed, but recovery has followed the taking of one ounce.

Fatal Period.—Is uncertain.

Treatment.—Siphon-tube with free lavage of starchy fluids, such as thin boiled arrowroot, cornflour, etc. Treatment, otherwise, should be conducted on general lines.

Chloroform, Chloral Hydrate, Bromoform, Iodoform.

CHLOROFORM ($CHCl_3$).—Deaths by chloroform may result from inhalation of the vapour, or from drinking the fluid, but so far as we know, only a few deaths have resulted from its homicidal use.[1] They are not infrequent while persons are being anæsthetised for surgical operations, but their number if reckoned into the total number of chloroform administrations, works out as a small fraction per cent. It has been our duty to make post-mortem examination of the bodies of several persons—men, women, and children—who have died while under the influence of this anæsthetic for surgical operations both trifling and severe, and we have entirely failed to find any appearance which might in any way be reckoned as characteristic. In only one of these was the odour of chloroform distinctly perceptible on opening the cavities of the body. Chloroform is but rarely taken in the liquid form for suicidal purposes, but cases have been recorded where death happened at variable periods of time thereafter, after doses of one and a half ounces, and one ounce respectively. We know of another case in which a medical man committed suicide in this way, but the quantity swallowed was not definitely known.

The *Symptoms* or effects of chloroform-inhalation being familiar to all students of medicine, it is not necessary to deal with them now. The lethal or toxic effects often come on so quickly and unexpectedly, however, that respiration, or heart's action, has ceased practically without any warning.

Treatment.—If the poison has been swallowed, the siphon-tube and free lavage of the stomach must be resorted to until the returning fluid ceases to have the odour of chloroform. Should respiration be embarrassed, artificial respiration should be employed, first alone, then afterwards with tracheotomy, along with the application of the electric current to phrenic nerves, inhalations of amyl nitrite, and the lowering of patient's head.

Post-Mortem Appearances.—Where the liquid has been swallowed, inflammation and erosion of mucous lining of stomach are likely to be found, along with a distinct, if not very marked, odour of chloroform. Where death happens during its effect as an anæsthetic administered as an inhalation, our experience is that but seldom is the odour perceptible in the body. In many cases, the post-mortem signs are those of death by syncope, in others, especially if there have been pre-existent lung lesions, those of asphyxia; but the latter are rare

[1] Casper-Liman, *Handbuch d. Ger. Med.*

Chloroform. B. M. J. Vol II. 1902. p. 1122. - Hayward.

[illegible] of carbon oxychloride or phosgene when Chlorof. is administered in neighbourhood of coal-gas jets

B. M. J. vol II, 1903, p. 1333-34

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compared with the former. According to certain observers the brain nerve-cell endings of certain animals killed by chloroform exhibit certain definite markings, but we have not found any such conditions in the brain-tissue of the bodies of those persons examined by us after death from this cause.

Chemical Analysis.—Where poisoning by chloroform is suspected, it is necessary to prove its presence or absence in the body. That is done by finely mincing up parts of the lung, rendering the fluid slightly alkaline by sodium carbonate, placing the material in a suitable flask closed by a stopper containing two openings, through one of which a glass tube is passed right to the bottom of the flask, and through the other, a piece of hard glass tubing about 18 inches in length and tapered to a point at the free extremity, which is bent twice at right angles, a . Through the former tube, air under pressure is passed into the flask, the flask and its contents being meanwhile gently heated, to assist in the disengagement of the chloroform from the mixture. While this is going on, a small Bunsen flame plays upon the latter tube, midway between the angles of the tube—at *a*—so that the tube is kept red-hot. When the chloroform vapour reaches this point, it is split up into chlorine and hydrochloric acid, which can be tested for in the usual way—the former by holding at the tapered extremity of the tube a piece of starch-paper moistened with pure freshly-prepared potassium iodide which it turns blue, and the latter by alkaline litmus paper which it turns red, or by passing the stream of gas into a solution of silver nitrate, which causes a white precipitate of silver chloride to form.

Another test may be employed to the clear fluid obtained from filtration of the contents of stomach, or of lung extract treated as above, viz., the β-Naphthol test. This is employed as follows: Into a test-tube put some β-naphthol, and add to it a few drops of strong potassium hydrate solution; then add two or three times the volume of the suspected solution, and gently warm the tube and contents; if chloroform be present, the mixture will turn blue.

CHLORAL HYDRATE ($C_2H_3Cl_3O_2$).—This substance is not infrequently used for suicidal purposes, and has been employed criminally by mixing it with beer or stout, with the object of stupefying persons for purposes of robbery. It is believed to act by being changed in the body into chloroform; but this view has been challenged by some observers. In one case of suicide by an intemperate man seen by us, the quantity taken to produce death was 220 grains. We have also been engaged in a case where a prisoner was convicted of drugging the liquor of his victims by putting syrup of chloral hydrate therein, so that he might the more easily rob them. On the person of the prisoner four half-oz. phials (empty) were found, the dregs of which proved to be chloral. Occasionally this drug has caused death by having been taken or given accidentally. In one case half an ounce of the drug was taken in gin in mistake for salts;[1] and the late Professor Tyndal met his death by accidental administration of an overdose of the drug. A woman suffering from bronchitis who was ordered one drachm of the syrup of chloral, but to whom, instead, was given one drachm of chloral itself, died within one hour.[2] The only fatal case to our knowledge resulting from the criminal administration of chloral, was tried at the Liverpool Assizes, in March 1889, when a man named Parton was charged with the crime of wilful murder of John Fletcher in Manchester. The prisoner was seen to empty the contents of a small bottle into a glass of beer. The prisoner and deceased thereafter entered a cab, but later, while the cab was proceeding at a walking pace, the prisoner decamped. Fletcher when found in the cab looked insensible, but was able to direct that he should be taken to the Royal Infirmary, where he died just as that institution was reached. It was proved that the prisoner tried to purchase of a Liverpool chemist forty grains of chloral, but failed to get that amount without a prescription. While the chemist, however, was weighing out ten grains for him, the prisoner snatched up the chloral bottle and ran off. Chemical analysis revealed indications of chloral in the stomach and intestines, but not in the blood of deceased. The prisoner was sentenced to death, but was afterwards reprieved.

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[1] *B. M. J.*, vol. ii. 1900, p. 468.

[2] Ibid., vol. i. 1884, p. 475.

Symptoms.—Drowsiness, going on to unconsciousness; slow, laboured respiration, with cyanosis of lips, and gradually weakening pulse; contraction of pupils, almost to pin-point; blanched, or cyanosed condition of face; subnormal temperature; failure of heart's action. Paralysis of the heart is the cause of fatal issues.

Treatment.—Use of siphon-tube with free lavage; restoration of body-heat; subcutaneous injection of strychnia; administration of ether hypodermically, or of stimulants *per rectum.*

Post-Mortem Appearances.—These are practically nil.

Fatal Dose.—Very uncertain. While so small a quantity as twenty grains has killed an adult, a boy of sixteen has recovered from the effects of swallowing one ounce.[1]

Fatal Period.—Is variable. It may be comparatively short, or it may be prolonged for several hours, depending upon the onset of paralysis of heart.

Chemical Analysis.—As chloral hydrate is soluble in ethylic ether, the contents of the stomach, after having been freely washed with petroleum ether to get rid of fatty matters, are treated with ethylic ether in a separator, the ether is then separated and allowed to evaporate, when the chloral will be deposited. The urine may be treated in a like manner, in which chloral may be found along with urochloral acid.

BROMOFORM ($CHBr_3$).—This liquid drug, which bears a close resemblance both in taste and colour to chloroform, has been much used of late years in the treatment of convulsive affections, and especially in whooping-cough. Its administration must be used with caution, chiefly by reason of its comparative insolubility in water, and its higher specific gravity (2·13) which is more than twice that of water. Burton-Fanning[2] recommended its use in whooping-cough, and that it should be prescribed in suspension with pulv. tragacanth co. and water, but owing to the high spec. gravity of the substance, in spite of this form of excipient, he found that it was liable to fall to the bottom of the bottle. He therefore advised that the last dose should be thrown away. From the difficulties of its equal admixture, cases of poisoning, fortunately as yet unattended by fatal results so far as we know, have occurred.[3]

Symptoms.—Unconsciousness, which supervenes rapidly; feeble, or stertorous respiration; weak, irregular, feeble pulse; marked contraction of pupils; and threatened collapse and death.

Treatment.—Use of siphon-tube and free lavage with warm water containing sodium carbonate or Condy's fluid, and, latterly, with coffee. Stimulants—as *sal volatile*, or alcohol—*per rectum.* Artificial respiration if necessary.

Toxic Dose in Children.—In a child of two, three or four minims have produced poisonous effects; and in one of six years, a drachm and a half imperilled life.

IODOFORM.—Iodoform is in common use as a surgical dressing, and causes toxic symptoms occasionally when absorbed from a large, raw surface. It has caused death when dissolved in ether and injected to render aseptic the interior of large chronic, or cold, abscesses. It has not yet been used with suicidal or homicidal intent. Eustace records a case in which a partially demented woman chewed an iodoform dressing, and thereafter betrayed toxic symptoms, the chief of which were cold extremities and delirium. She recovered. Oberlander records two cases, in which from its internal administration (·8 gramme daily in a pill) toxic effects were evinced when, in the one case, 42 grammes in all had been taken, and in the other, 5 grammes covering a period of seven days.

Symptoms.—When absorbed into the body from surgical dressings, it causes gastro-intestinal irritation, rise of temperature, and skin-eruptions. After injection, it has produced unconsciousness, with delirium, coma, and death. The symptoms were giddiness, vomiting, deep sleep, delirium, diplopia, and Cheyne-Stokes' respiration.

Sulphonal, or Disulphonethyl-dimethylmethane.—This is one of the comparatively new drugs for inducing sleep, and is used by patients just as opium or morphia by repeating prescriptions without further medical advice. It is a

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1 (Plummer) *The Lancet*, vol. i. 1894, p. 21. 2 *Practitioner*, Feb. 1873.
3 *B. M. J.*, vol. i. 1900, p. 1283; idem, vol. i. 1900, p. 1340; idem, vol. i. 1901, p. 1202.

crystalline substance, sparingly soluble in water but more freely in alcohol. Many cases of poisoning have already been recorded from its use in overdose. Waldo[1] records a case of a man of thirty-three years who had been in the habit of taking hypnotics, and chiefly sulphonal, for several years. He developed pain and tenderness over the stomach, attended with nausea, vomiting, and delirium at nights. He gradually passed into a state resembling delirium tremens. His urine had a port-wine appearance, and smelt like chlorodyne or celery on different occasions. Four days before death, general convulsions set in. No urine was passed for forty-eight hours. The urine being submitted to spectroscopic examination showed the presence of hæmatoporphyrinuria—an iron-free pigment—which exhibits two spectra depending upon whether the urine be acid or alkaline; in the former, there is a narrow band between C and D close to the D line, and a second much broader band between D and E; in the latter, there is one band between C and D, two bands (distinct) between D and E, and a fourth broad band between E and F. Calvert relates a case in which a servant-maid had this condition of hæmatoporphyrinuria without having taken sulphonal.[2] Keith Campbell[3] records a fatal case with this urinary condition following the use of 30 grains of the drug in two doses. Knaggs[4] narrates the case of fatal poisoning in a man who took over an ounce of the drug, and died at the end of three days. Several other cases are recorded in Continental medical journals.

Fatal Dose.—Thirty grains have killed; on the other hand, recovery has followed the ingestion of three ounces.

Treatment.—Evacuation of contents of stomach. This appears to be a form of poisoning in which bleeding and transfusion of live human blood ought to be tried.

Chemical Analysis.—There does not appear to be any method yet devised for its detection in the body, owing to its being decomposed. The spectroscopic detection of hæmatoporphyrinuria would afford strong suspicion of its use.

Trional, or Diethylsulphonmethylethylmethane.—This synthetic drug has been recommended as a safer substitute for sulphonal, but from recorded cases of its toxic effects, it ought to be used, if at all, with great caution. Mosso in 1894 demonstrated that it was cumulative in its action, and from the symptoms produced there is suggested an affinity for groups of nerve cells in the anterior cornua of the spinal cord, in this being not unlike the action of some metallic poisons. Hart[5] records the case of a woman who had taken during two months about thirty 15-grain doses of the drug, and at the end of the time was seized with acute gastro-intestinal inflammation. The urine became black in colour five days after, and contained hæmatoporphyrinuria. A few days later tingling of arms and legs, with diminished sensibility, loss of power, and decreased reflexes, followed. Three weeks after the onset there was well-marked double wrist-drop and foot-drop, loss of weight, delirium, and hallucinations. She recovered over a year after. Other cases, fatal and non-fatal, are recorded in Continental medical journals.

Fatal Dose.—Not well ascertained.

Treatment.—This must have special reference to the profound changes in the blood, whence arise the symptoms referred to. Whether repeated bleedings and transfusions of blood are likely to act beneficially remains yet to be tried; but they are undoubtedly indicated.

Hydrocyanic or Prussic Acid (HCN).

Hydrocyanic acid when pure, is a colourless, volatile liquid, evolving a strong odour of peach-blossom, laurel-water, or of bitter almonds. It is but feebly acid, reddening litmus paper but slightly. The Pharmacopœial preparation contains about 2 per cent. of the anhydrous acid, and that of Scheele, which is the only other preparation sometimes used in this country, about 5 per cent. The former preparation, however, has been found to contain as little of

[1] *B. M. J.*, vol. i. 1901, p. 1473.
[2] Ibid., vol. ii. 1900, p. 1784.
[3] *Jour. of Ment. Sci.*, Ap. 1898.
[4] *B. M. J.*, 1890, vol. ii. p. 955.
[5] *Amer. Journ. of the Med. Sci.*, Ap. 1901; *B. M. J.*, vol. i. 1901, supp. p. 87.

the acid as 0·6 per cent., and as much as 3·2 per cent., while the latter has been found to vary between 2 and 8 per cent. When inhaled, its odour causes a feeling of chokiness or constriction in the throat. It has a pungent, acrid, or bitter taste. It has never been found as a natural constituent of the body, although traces of sulphocyanides are found in the saliva. It is not a product of putrefaction so far as is known, but it may be formed by burning organic matter with alkalies at a red heat, the carbon and nitrogen of the former uniting with the latter to form cyanides. It is not found in nature as such, but in the kernels of various fruits, as of hawthorn, peach, plum, bitter almond, apple pips, and others, amygdaline and emulsine exist which react upon one another in presence of water and form the acid; in like manner may it be said to exist in the leaves of cherry-laurel, a preparation of which is used in medicine, and which contains about 0·08 to 0·1 per cent. In oil of bitter almonds it exists in much larger percentage than in preparations from other fruits, the quantity of acid varying from 8 to 15 per cent. "Essence of almonds," which is the oil dissolved in spirit, is very poisonous. The eating of bitter almonds has produced toxic effects on more than one occasion.[1] A clergyman at West Malling, Kent, prescribed for a young girl, a parishioner, and administered to her some oil of bitter almonds, from which she died. The coroner's jury returned a verdict of manslaughter.

Hydrocyanic acid combines with bases of several metals to form cyanides, those of the alkalies and alkaline earths being soluble in water, alkaline in reaction, and therefore give off HCN in presence of even the feeblest acid; those of the heavy metals, as mercury, zinc, lead, copper, and others possess no odour, are insoluble in water, but give off HCN in presence of mineral acids. In addition, it combines with metals to form double cyanides, such as the ferro- and ferri-cyanide of potassium; and in combination with sulphur, forms sulphocyanides or thiocyanates with alkalies and alkaline earths, iron, mercury, etc. All of the sulphocyanides, however, possess no odour, are poisonous, and give off HCN when distilled with acids.

Of these preparations the most likely to cause poisoning are (1) oil of bitter almonds, (2) cyanide of potassium,[2] which is used in photography, electro-plating, and gold-recovery, and (3) hydrocyanic acid itself. Laurel-water, however, has also caused poisoning.

Symptoms.—These to some extent depend on the preparation which is swallowed, and its quantity. In large doses, it produces death almost instantaneously, with lightning-like action; but during the act of swallowing, a hot, bitter taste is said to be experienced in the mouth. Whether this be so or not, after a convulsive cry, complete loss of consciousness and muscular power almost immediately supervene, with hurried respiration, sometimes convulsive, sometimes stertorous, imperceptible pulse, coldness of extremities, prominent, glistening, staring eyes with dilated pupils, which are non-reactive to light; then follow convulsive seizures, and death. If death be not so rapid, froth may appear at the mouth, and relaxation of sphincters of bowel and bladder may take place with voidance of contents.

[1] *South Australian Register*. Aug. 6, 1879; *B. M. J.*, vol. ii. 1881, p. 12. (Baker.)
[2] *B. M. J.*, vol. i. 1884, p. 228.

In poisoning by potassium cyanide the rush of symptoms is not so rapid. These symptoms are as follows: convulsive seizures, insensibility; odour of prussic acid in breath, and in vomited matter, should there be vomiting; face somewhat cyanosed; foam or froth at mouth; jaws tightly clenched; respirations jerky, hiccoughy; pulse small and rapid; eyes staring and fixed, with marked dilatation of pupils; and convulsive position of fingers in hand. Cases of poisoning by this salt may be consulted in the following references.[1]

The proximate cause of death is through the nervous system; but whether this is effected by the direct operation of the poison upon the central nervous system as is held by Preyer or others, or upon the vaso-motor centre or the respiratory centre as is held by other observers, is not yet quite clear. But it must be remembered that hydrocyanic acid acts upon hæmoglobin, forming a compound which has been called cyanmethæmoglobin, which cripples the oxygen-carrying function of the red corpuscles. There is nothing, therefore, to interfere with the hypothesis that the effect of the acid upon the blood is to produce convulsive seizures and early insensibility, as the result of the conveyance of imperfectly-oxygenated blood to the nerve-centres.

Post-Mortem Appearances.—Externally these are: open, fixed, staring eyes with dilated pupils, froth at the mouth, fixation of jaws, and convulsive attitude of hands. In addition to these, the colour of p.-m. lividity is sometimes pinkish or rosy, although not so pronounced as in CO poisoning. Internally, the signs are remarkably negative. Owing, however, to the red colour of cyanmethæmoglobin which is formed, the mucous membrane of stomach may be of a reddish hue. The blood is usually dark in colour; it is never bright-red as in CO poisoning. Moore gives an account of the appearances found in the internal organs of a man of 28 who died from the effects of swallowing about half a tumbler of a saturated solution of the cyanide. He had not vomited, and lay as if asleep. The stomach and gullet were of a peculiar reddish brown colour, and were very much wrinkled; but there was no hæmorrhage, nor was the mucous membrane detached at any point. All the cavities of the heart contained imperfectly clotted blood; the lungs were engorged; the brain was normal, as were also the small intestines.[2] Spectroscopic examination of the blood ought to be made in such cases, for the compound of HCN and hæmoglobin is fairly stable, and its presence is betrayed by the following spectrum, viz.: bands resembling those of reduced hæmoglobin, and which are not affected by NH_4HS.

Death most usually happens from asphyxia, hence the signs of this form of death are present

Fatal Dose.—The smallest dose which has been shown to be fatal was half a drachm of the B.P. acid, which if reckoned to contain 2 per cent. of the anhydrous acid, is equal to 0·6 grain of anhydrous hydrocyanic acid.[3] Probably the next smallest was 20 grains of

[1] *B. M. J.*, vol. i. 1896, p. 17; idem, vol. i. 1897, p. 1039; *The Lancet*, vol. ii. 1889, p. 42; *Chem. News*, 1861, p. 261.
[2] *B. M. J.*, vol. i. 1882, p. 740.
[3] Garstang, *The Lancet*, vol. ii. 1888, p. 15.

Scheele's acid, equivalent to 50 grains of the B.P. acid, and to one grain of the anhydrous acid.[1] On the other hand, recovery has followed the use of much larger doses, as 1·3, 2·3, and 4·8 grains of anhydrous acid respectively.[2] The vapour of the acid has caused the onset of dangerous symptoms, and, according to Christison, the application of the acid to a wound upon the hand caused death one hour afterwards. From the foregoing it may be taken that one drachm of the B.P. acid will kill. Two drachms of the oil of bitter almonds killed a man in seventeen minutes.[3] Five grains of the cyanide of potassium has produced death, but recovery has followed larger doses.

Fatal Period.—This usually falls within five minutes; but cases have been recorded where persons have survived its use for twenty minutes and longer. In a case of suicide, in which a woman swallowed a weak preparation of the acid, death did not ensue for forty minutes.[4] In another suicidal case of a young woman in Belfast, life was prolonged for $3\frac{1}{2}$ hours after taking the poison, which she had taken in milk.[5]

Cases of homicidal administration are fortunately few. In March, 1845, at the Spring Assizes, Aylesbury, John Tawell was tried and convicted of poisoning a woman with prussic acid given in porter. The poison was discovered on chemical analysis in the contents of the stomach of the victim, and purchase of prussic acid by the prisoner was proved in evidence. In July, 1860, at Lewes, a medical practitioner—George Ball—was tried for administering prussic acid to his mother, from the effects of which she died. This was really a case of poisoning by misadventure, and the jury returned a verdict of "Not guilty." At the Circuit Court, Glasgow, in Dec. 1857, Peter Walker was convicted of feloniously administering the acid to a woman, Agnes Montgomery. The poison was found in the stomach on post-mortem examination of the exhumed body. The prisoner confessed his guilt after sentence of death had been passed. Oil of Bitter Almonds was the form of poison administered by the prisoner Timmins who was tried at the Maidstone Assizes in 1883.

Treatment.—Immediate use of siphon-tube, and free lavage with warm water either alone or containing a 5 to 10 per cent. solution of sodium thiosulphate, or a mixture of the sulphates (ferrous and ferric) of iron followed by a solution of potassium carbonate, to form Prussian blue, which is inert; emetics, if tube be not available; stimulants, as ether subcutaneously, or brandy *per rectum;* cold effusions; artificial respiration; electricity to phrenic nerves and chest.

Chemical Analysis.—As hydrocyanic acid and its soluble compounds are rapidly decomposed in the body, examination for the poison should be made as soon after death as possible; and the same is true of any suspected articles of drink or medicine.

I. The first thing to note of the contents of the stomach, or articles of drink, is the presence or absence of the tell-tale odour; at the same

[1] *Med. Gaz.*, vol. xxxv. p. 896.
[2] Shively, *Internat. Jour. Med. Sciences*, vol. 100, 1890, p. 47; *B. M. J.*, vol. ii. 1890, p. 1120.
[3] *The Lancet*, 1863, p. 447.
[4] Ibid., vol. ii. p. 864.
[5] *B. M. J.*, vol. i. 1883, p. 131.

time, the absence of the characteristic odour does not prove the absence of the poison.

Advantage should next be taken of the *volatile nature* of the poison for its detection. To test this, place a portion of the stomach contents, or other substance, into a wide-necked glass jar, covered with an inverted shallow glass or porcelain capsule. On the concave side of the glass capsule put a drop of silver nitrate solution; place the jar, etc., into a vessel of warm water; and note whether or not the silver solution becomes turbid. If it do so, owing to the formation of a new salt of silver, the new compound may consist of the chloride, carbonate, bromide, iodide, or cyanide. To distinguish between these — the mouth of the jar being meanwhile carefully stoppered—the precipitate should be examined microscopically for the presence of crystals, in the form of granules, prisms, and needles; it should next be noted whether or not the white precipitate darkens on exposure to light, for if it does, it is likely to be chloride of silver; if it do not, add a tiny drop of NH_4HS and evaporate to dryness, then dissolve the residue in water, add a drop of a *per*-salt of iron, and if HCN be present, a brilliant red colour of the sulphocyanide of iron will form, thus distinguishing it from the other salts of silver.

II. If a white porcelain capsule be now inverted over the mouth of the jar, having upon its concave side a mixed drop of solution of caustic potash and of solutions of a *per*- and *proto*-salt of iron, the presence of HCN is indicated by the drop assuming a bright blue colour, which becomes still more marked by the addition of a drop of hydrochloric acid, owing to the formation of Prussian blue ($Fe_4 3FeCy_3$).

III. Another white porcelain capsule having on its concave side a drop of NH_4HS should now be placed over the mouth of the jar. Even in the presence of HCN no visible change takes place in the drop, owing to the fact that the sulphocyanide of ammonium is colourless, but if a drop of perchloride of iron be added, a beautiful red colour will at once be struck. Stewart has suggested a very ingenious apparatus for carrying out the vapour tests. It consists of a shallow glass jar, closed by an india-rubber stopper carrying at right angles two glass rods ending in glass spoon bowls, into which the silver and potash solutions respectively are put. The prepared apparatus is then placed in a warm position for six or eight hours, the two rods removed, and a third, containing NH_4HS, substituted.[1] To the contents of the spoon bowls the above liquid tests are applied.

Quantitative Estimation.—An aliquot portion, previously estimated, of contents of stomach is placed in a retort, connected with a well-fitting condenser, and distilled, the distillate being collected in an ordinary receiver. Thereafter the contents of the receiver are acidulated with dilute nitric acid and excess of silver nitrate is added. The precipitate being washed and dried, is then weighed, 100 parts of the precipitate being equivalent to 20·15 of anhydrous prussic acid.

If prussic acid be thus obtained, and the contents of the stomach were not found markedly acid in preliminary testing, then there can be little doubt that the HCN existed in the free state. In order, then, to distinguish between poisoning by free HCN and by an alkaline

1 "Trials for Murder by Poisoning," p. 72.

cyanide, a portion of the reserved fluid may be directly tested with a mixture of the *per-* and *proto-*salts of iron, and if Prussian blue be formed, it may be concluded that the HCN existed in the form of an alkaline cyanide.

Should the HCN not come over by simple distillation, it will be necessary before redistilling to acidulate the mixture with sulphuric acid; or should it be apparent that the poison existed initially as an alkaline cyanide, the acid should be added before the mixture is first distilled. By this method, however, it must be remembered that HCN may be evolved from the ferro- or ferri-cyanide of potassium.

The blood and bodily tissues may also be tested in the foregoing manner.

Failure to detect the poison in the body may result from undue delay, but notwithstanding its volatility and liability to decomposition, it has been detected weeks and months after death; for example, Reichardt[1] found it in a body two months after death. That it is liable to rapid decomposition in the body under certain circumstances is apparent from the fact that, as Casper states, Schauenstein, one of the Prussian official chemists, failed to find it 26 hours after death, but found *formic acid*, the main product of the metamorphosis of the poison in the body. It is important, therefore, that the presence of formic acid should be sought for, and its amount estimated in those cases in which poisoning by HCN is suspected, but where the poison as such cannot be found on analysis of the bodily organs.

Opium.

Nat. Ord. = Papaveraceæ. — Opium consists of the inspissated juice of *Papaver somniferum*, and contains a large number of alkaloids, as morphin, narcotin, codein, narcein, thebain, apomorphin, anarcotin, and others, several of which are highly poisonous; the neutral substance called meconin or opianyl; and meconic acid. The principal alkaloids in use in medicine which are obtained from opium are morphia or morphin, codeia, and apomorphin, of which the first two act as narcotics or sedatives, the last chiefly as an emetic. Opium and morphia enter into the composition of a number of officinal preparations as well as of patent medicines, as for example, chlorodyne, nepenthe, Godfrey's cordial, Dalby's carminative, Winslow's soothing syrup, Battley's solution, Locock's pulmonic wafers, and others.

Cases of poisoning may arise from any of the preparations which contain opium, but the commonest forms are laudanum, chlorodyne, and of the preparations of morphia, any soluble salt of the Pharmacopœia.

Symptoms.—These appear earlier from the use of morphia than from crude opium or its preparations, and they may be divided into two groups, viz.: those indicative of excitation of the higher nerve-centres, and those indicative of narcosis. When a case calling for treatment usually comes under notice, the former symptoms will have passed away, and the latter are fully developed. The latter symptoms

[1] *Archives Pharmac.*, iii. 19, 204.

especially, therefore, demand consideration, and consist of the following, viz.: an overpowering condition of drowsiness, which gradually becomes deeper until it ends in profound insensibility so that no stimulus can arouse; although in the earlier stages, however, the person may be partially roused to consciousness. In the later stages, the muscles become relaxed, the pulse small and weak, and the breathing laboured, noisy, and it may be, irregular, while at a later stage it becomes shallow and slow; the face is pale, cold, and sometimes bedewed with clammy perspiration; and the pupils are strongly contracted, almost to pin-point in size. Death may succeed the deepening of the narcosis, or it may be preceded, especially in children, by convulsive seizures.

It occasionally happens that there may be a remission of the symptoms for a short period of time, but they return in all their original severity from which the person may die. The reader is referred to a case of this kind recorded in a previous chapter.

The symptoms of opium poisoning may be complicated or masked by its having been taken with other drugs. Dr. Gregory reports a case of a lady who at 9.30 A.M. took for toothache 17 drachms of laudanum, and at 10.30 P.M. 60–70 grains of Antipyrin. At 5 A.M., when the doctor saw her, she was in an excited condition, but answered questions readily and distinctly. Her temperature was 99° F., the pulse 100, and the pupils normal and responsive to light. When the stomach was washed out $19\frac{1}{2}$ hours after the taking of the laudanum, the returning fluid smelled most strongly of that drug. She made a good recovery.

Infants and young children are most susceptible to the influence of opium and morphia. One drop of laudanum has many times proved fatal. For this reason, therefore, the administration of the drug to children should be avoided, and the use of patent medicines which contain them strongly denounced. While death from an overdose is the rule, astonishing recoveries are sometimes experienced. Fotheringham states the facts of a case in which an infant 3 months old recovered after the administration of a teaspoonful of liq. morphinæ in mistake for fluid magnesia. The tea-spoon, on measurement, was found to hold 75 minims, and allowing for a little to be lost while being given, it may be reckoned that the infant swallowed 60 minims of that preparation of morphia.[1] Doernberger[2] narrates another case in which an infant recovered from the effects of "sedative tea" prepared from the green capsules of the poppy.

Self-administered injections of morphia in overdoses may also produce poisoning. One must therefore be alive to this form of administration, and examine for evidence of needle-pricks on those parts of the body available for self-administration. (*Vide* Fig. 24, p. 66.)

Post-Mortem Appearances.—As death is from coma, the p.-m. signs will be found of this kind of death, or of comato-asphyxia. If the case has been untreated, and if opium itself or laudanum has been taken, the odour of the drug may be perceived in the stomach. If the stomach has been washed out, the odour should be perceived during the operation. It may very well happen, if morphia has been

[1] *B. M. J.*, vol. ii. 1898, p. 1251. [2] *Münch. med. Woch.* Ap. 13, 1897.

taken, that nothing may be found in the stomach indicative of the fact. Moreover, the examiner has to bear in mind that opium may be introduced into the body by other channels than the stomach, as, for instance, by the rectum. Dr. Heron Watson has informed us of a case where the poisoning was due to a piece of opium introduced by the person into the rectum to allay the pain of hæmorrhoids.

Treatment.—This must be regulated by the condition of each individual case, with respect to the time of swallowing the poison, if it has entered the body by the mouth, or of injection where it has been used hypodermically. In the former case, the siphon-tube must be used with free lavage of the stomach, first with simple warm water, and then with warm water in which 10 to 15 grains of potassium permanganate to the pint of water are dissolved. This line of treatment by permanganate was first suggested by Dr. Barber Smith in 1884 (Maynard). There can be little doubt from the experiments of Moor upon himself with this salt, having taken on two occasions three and five grains of sulphate of morphia respectively, followed thereafter by four and eight grains of permanganate within a few seconds after the morphia, and no harmful results succeeding, and from his observations on the result of this treatment of 35 cases of opium poisoning with success, that permanganate of potash oxidises the alkaloids of opium into harmless compounds.[1] Raw's six cases corroborate the value of the treatment.[2] Luff subjected this treatment to chemical experiments *in vitro*, by mixing vomited matter with known quantities of morphia, and then with known quantities of permanganate. After agitating the mixture at intervals of half an hour, it was then mixed with alcohol acidulated with acetic acid, filtered through linen, and the filtrate evaporated to a syrupy consistence at 35° C. This was extracted with successive drenchings of absolute alcohol, which were filtered, and the alcohol evaporated. The residue was then treated with water acidulated with acetic acid to dissolve any morphin unacted upon in the vomit, and the fluid was then filtered; the filtrate was then made alkaline by ammonia, shaken up with double the volume of hot amylic alcohol, which, on separation of the fluids, was removed, and this operation was repeated two more times; after which the amylic alcohol extracts were united, filtered, and evaporated to dryness over a water-bath. The residue which remained was then dissolved in a little water acidified with acetic acid, the solution filtered and concentrated, and then a little ammonia was added. This was then allowed to evaporate spontaneously, and the residue examined for morphia. Where 5 grains of morphia were added to the vomit, and subsequently 7 or 8 grains of permanganate dissolved in eight ounces of water, no morphia could be extracted as above; and the same result happened in other experiments with 3 grains of the one and 4 grains of the other.[3] Maynard records the results of 19 cases of poisoning treated by this method at the Medical College Hospital, Calcutta, at varying intervals after the poison had been taken, and from varying doses—from 360 grains downwards—

[1] *B. M. J.*, vol. i. June 22, 1895.
[2] Idem, vol. ii. 1895, p. 76; idem, vol. i. 1896, p. 82.
[3] Idem, vol. i. 1896, p. 1193.

of the poison. Of the 19 cases 13 recovered, and 6 died.[1] Luff, in the paper quoted, makes the further suggestion, that even in those cases in which the morphia has been administered hypodermically the permanganate treatment ought to be adopted because morphia is excreted by the stomach. Maynard suggests also the use of permanganate solution acidulated with sulphuric acid, because of the comparatively greater insolubility of the sulphate than the acetate of morphia in water. In the presence of an acid, too, permanganate has greater oxidising power. Gowring has also recorded a case of recovery by this treatment;[2] and Walker, of one from morphia poisoning[3] by 16 grains of the sulphate. It is important to remember that permanganate must not be used in too strong solution as it is slightly corrosive in its effects; indeed, one case has been recorded of this kind where such effects were produced.[4]

While permanganate of potassium may, therefore, be expected to neutralise any opium or morphia upon which it can act in the stomach, it will be necessary to combat the toxic effects of that portion which has been absorbed, and from which the symptoms present arise. The physiological antidote is atropia. For this purpose $\frac{1}{20}$th to $\frac{1}{12}$th of a grain of atropin sulphate may be injected hypodermically in an adult, and from the $\frac{1}{300}$ to $\frac{1}{150}$ of a grain in infants, with a gradual increase of dose in children and young persons up to the amount first named.

Ernest Bashford[5] has made an exhaustive investigation on the subject of the antagonism of atropia and morphia by experiments on white rats. From these experiments he concludes that in morphin poisoning not more than 1·5 mg. (about $\frac{1}{12}$ grain) of atropin should be injected, and that the dose should not be repeated. He further affirms that it is uncertain whether the antagonism between these toxic agents is mutual; that is, whether morphia would act as an antidote to atropia as the latter does to the former, which is the view of some observers. In all cases of poisoning, the bodily heat must be restored by suitable restorative measures, and it is not wise practice to subject a patient to too vigorous or prolonged muscular exercise. In the immediate absence of a siphon-tube, emesis should be promoted and encouraged by the readiest emetic, and stimulation by the use of strong coffee. Where the heart's action appears to be failing, injection of ether under the skin, or alcohol *per rectum* is called for. In infants, a soft rubber catheter with enlarged eyes may be utilised as a siphon-tube with any kind of funnel which is convenient.

Fatal Dose: Infants.—One drop of laudanum has killed on more than one occasion, and an amount of compound tincture of camphor containing the $\frac{1}{10}$th of a grain of opium has produced the same result. Children have, however, recovered from large doses; of $7\frac{1}{2}$ grains of opium,[6] from one and two teaspoonfuls of laudanum, and from 60 minims of liq. morphinæ.[7] We have seen recovery in a child of nine

[1] *B. M. J.*, vol. i. 1896, p. 1194.
[2] Idem, 1896, p. 785.
[3] Idem, 1896, p. 82.
[4] *Petersburg. med. Woch.*, 1895.
[5] *Arch. Internat. de Pharmacodyn. et de Thérap.*, vol. viii. fasc. 3 and 4, 1901.
[6] *Med. Gaz.*, May 1859, p. 505.
[7] *Vide ante;* and *The Lancet*, vol. ii. 1889, p. 1113.

months after 15 drops of laudanum, and that without recourse to any special treatment.

Adults.—Four grains of opium and one grain of morphia respectively may be deemed as likely fatal doses, as they have produced such results. Recovery has, however, followed treatment where 360 grains of opium have been taken;[1] 55 grains of morphia acetate;[2] and in a case which we treated, from one and a half bottles of chlorodyne.

Fatal Period.—As early as forty-five minutes[3] (Lyman) in a female aged 52, from one ounce of laudanum. The usual period is from 9 to 12 hours. It may however cover days; in one case where 10 grammes of a liquid preparation of opium was injected in an adult instead of 10 drops, death did not happen till 2 days;[4] and in a child of three months, not until after 56 hours.[5]

Chemical Analysis.—In conducting an inquiry on a death from presumed opium poisoning, it is essential in the examination of the stomach-washings, vomit, and contents of the stomach, to carefully note any odour of opium or its preparations, both in the cold and when gently heated, and also whether there are small pieces of opium in the contents, lest the crude drug has been swallowed. The absence of odour, however, is no index to the absence of the poison, since it may be masked by other odorant materials, or it may be absent owing to a preparation of morphia having been taken. In the analysis for opium, the presence of meconic acid and morphia are sought for; indeed, the discovery of the former alone is sufficient to establish the presence of the drug, but it is better if possible to demonstrate also the presence of morphia. If the liquid to be examined consists of comparatively clear stomach-washings, acidulate it with acetic acid, evaporate at low temperature to a small volume on a water-bath, and filter. To the clear filtrate, add slight excess of acetate of lead, which will precipitate the meconic acid as meconate of lead, along with albuminous matter. After the precipitate has settled, filter through a small moistened filter, and wash the residue in the filter with distilled water. Both the filtrate and residue must next be carefully examined; the former for morphia, the latter for meconic acid.

I. *Examination of Residue in Filter.*—The filter-paper being still moist, perforate its apex, and carefully wash its contents by a wash-bottle into a long test-tube; allow the precipitate to settle, and decant some of the supernatant clear fluid. Shake up the precipitate in the remaining fluid, and pass H_2S for some time through it to ensure complete precipitation of lead sulphide. The meconic acid will now be in solution. Filter the whole; and concentrate filtrate on water-bath to dissipate excess of H_2S. Allow concentrated solution to cool. Transfer a drop of it to a watch-glass, and touch the drop with a glass rod dipped in a solution of a *per*-salt of iron; if meconic acid be present, a colour ranging from red to blood-red will develop, which is not affected by the presence of a free mineral acid, but which is discharged on adding a drop of a solution of protochloride of tin, but is

1 Maynard, *vide ante.*
2 Bonjean, *Annal. d'Hygiene,* 1845.
3 *Amer. Jour. Med. Science,* October 1854.
4 *The Lancet,* Ap. 1851, p. 435.
5 *Med. Gaz.,* March 1858, p. 292.

not discharged by mercuric chloride, as is the red sulphocyanide of iron. Should this reaction be absent or only show a faint response, concentrate the residual liquid still further, and again test. Should even this fail, gently evaporate the residual liquid to dryness, extract it with a small quantity of strong alcohol, filter, and evaporate to dryness; then dissolve dry residue in a few drops of warm water, and test as before. If no reaction appear, meconic acid is not present, since by the above method, carefully conducted, $\frac{1}{100}$ of a grain of the acid may be detected.

II. *Examination of the Filtrate.*—If morphia has been initially present, the filtrate ought to contain it in the form of acetate, along with any excess of lead-acetate which may not have been precipitated by inefficient use of H_2S. It is better, therefore, first to pass H_2S through the filtrate to test this, and if a precipitate forms, after thorough settling the liquid is filtered, and is evaporated to dryness on the water-bath; the residue is then dissolved with a little distilled water, and again filtered. A drop of the filtrate may then be tested by nitric acid, when the presence of morphia will be indicated by the development of a lemon-yellow to orange-red colour; and another drop, by the solution of iron, when, if no free acid be present, a blue colour will be struck. The remaining fluid, after being slightly diluted with water, is alkalinised by a strong solution of potassium carbonate, and after standing for some time is shaken up with *absolute* ether. This ether extracts some colouring matter and derivatives of opium, but the morphia remains dissolved in the aqueous alkaline fluid. The ether being separated and set aside for further use, the alkaline liquid is now examined for morphia. This may be done in different ways. (1) Shake up the liquid for some time with five times its volume of a mixture of two parts of absolute ether and one part pure alcohol. After separation of the liquids, decant, or pipette off the alcohol-ether solution, allow it to evaporate spontaneously in a watch-glass, when, if morphia be present, it will be deposited as crystals. These crystals or some of them may be dissolved in a drop or two of distilled water, and tested with nitric acid and iron, to demonstrate the presence of morphia.

(2) By extraction of the alkaline solution with hot amylic alcohol.[1] This process is carried out by shaking up the aqueous alkaline solution with two or three times its volume of the hot alcohol, allowing the liquids to separate, pipetting off the alcoholic layer into a watch-glass, evaporating it at gentle heat on a water-bath to dryness, when the crystals will separate out. If, however, there be only an amorphous residue, it should be re-dissolved in ordinary dilute alcohol, and evaporated spontaneously. Tests for morphia may then be applied. Certain objections have, at the same time, been offered to this method; for example, that the amylic alcohol may contain coloured and resinous substances due to furfural; again, it dissolves urea and extractives, which prevent the ultimate purification of the morphia.

III. *Extraction of the Alkaline Solution by Acetic Ether.*[2]—The manipulation of the process is practically identical with the fore-

[1] Uslar and Erdmann (*Liebig's Annalen*, 1861, vol. 120).

[2] Valser, *Chem. News*, 1864, vol. ix. p. 289; *Jour. Pharm. et Chimie*, xlii. 49, 63.

going. It is objected to this process that morphia is much less soluble in pure acetic ether than in either of the solvents of the other methods. It has, however, this advantage, that after evaporation it is more likely than the amylic alcohol process to leave the alkaloid in the crystalline form.

IV. *Extraction by Mixture of equal parts of Acetic and Ethylic Ethers.*—In using this process the alkali should be added to the residual fluid in presence of this solvent, and after due agitation the separation should be effected at once.

Liquid Tests for Morphia and Meconic Acid.

1. Nitric Acid gives with concentrated solution of Morphia a rich orange colour; better, if it be added to the crystalline alkaloid.

2. Ferric Chloride solution gives with Morphia in neutral solution a deep blue colour, which on the addition of nitric acid acquires an orange-red colour. With meconic acid ferric chloride gives a deep blood-red colour which is not discharged by mercuric chloride as is the red sulphocyanide of iron, nor by hydrochloric acid as is the red ferric acetate.

Atropa Belladonna, or Deadly Nightshade.

Nat. Ord. = Solanaceæ.—This plant is a native of Great Britain. It has pointed, entire, smooth, unequal leaves in pairs, its flowers are bell-shaped, hanging, and of a dull reddish colour. It flowers in July, and fruits in September, its fruit being a jet-black, or deep violet berry about three-fourths of an inch in diameter, which on expression gives a violet-coloured juice. The root is cylindrical in shape, varies in length from several inches to two feet, appears reddish-brown or brownish-white in colour externally, is branched and tapering, and possesses a sweetish, or sweetish-bitter taste. All parts of the plant are poisonous to man; but rabbits may be fed exclusively on the leaves for days together without inconvenience (Ogle), although it produces dilatation of their pupils as in man; pigeons seem to be able to take 3 grains of the alkaloid without harm, and without pupillary dilatation.[1] The root and leaves are used in medicine. From the root the alkaloid *atropia* is obtained. Atropia or Atropine ($C_7H_{23}NO_3$), which was discovered by Mein in 1831, occurs as silky, prismatic, and needle-like crystals often aggregated together, and has a bitter, burning taste.

Preparations of the leaves and the root of the plant and of the alkaloid form some of the official drugs of the Pharmacopœia. The eating of the berries has given rise to poisonous and fatal effects on several occasions. A man and a child who partook of a pie made with them and apples both died.[2] At an inquest held at Morecambe, September 1889, on the cause of death of a boy, it was shown in evidence that he had eaten black berries by the roadside, and the jury returned a verdict of atropine poisoning.[3] This case is, to our mind, not clearly proved. Medicinal preparations occasion toxic symptoms. Scott records an interesting case of five boys, who finding some sweet "stuff" tasting of liquorice, swallowed varying amounts of it, and thereafter

1 Wood's "Therapeut.," p. 233.
2 *New York Jour. of Med.*, vol. viii. p. 284.
3 *The Lancet*, vol. ii. 1889, p. 706.

developed the toxic effects of belladonna. The stuff consisted of an electuary of belladonna and liquorice, and contained ʒii of belladonna extract to the ounce, and the quantities taken by the boys varied from half a teaspoonful upwards. They all recovered.[1] A tablespoonful of the liniment produced toxic symptoms in a lady, from the effects of which however she recovered.[2]

Cases of poisoning by the liniment taken accidentally or suicidally, are also recorded. In one, a wineglassful was taken,[3] and chloroform had to be administered to allay the great excitement of the patient; in a second, two ounces and two drachms were swallowed. Pilocarpin, hypodermically, acted very beneficially in this case.[4] In a third case, a boy of two and a half years drank a quantity equal to about four drachms of the extract. They all recovered.

From its use as an external application and as an enema, serious and fatal results have also happened. We have seen toxic symptoms after the use of a 2-grain pessary.

Cases of accidental and suicidal poisoning by the alkaloid are comparatively rare, and criminal poisonings still rarer. Dr. Oliver[5] has reported a very interesting case of suicidal poisoning by the alkaloid, a summary of the facts of which is as follows. A young woman of twenty-one was admitted to the Newcastle Royal Infirmary, having taken nearly one ounce of "eye-drops" (four grains of atropine sulphate to the ounce) twelve hours before, while she was drunk. Attempts had previous to hospital treatment been made to induce vomiting, but without success. Her condition on admission was as follows: her face was flushed, the lips dry and blistered, tongue and mouth dry, eyes prominent, conjunctivæ injected, pupils widely dilated and immobile; there were twitchings of fingers and toes, with tremors. She was delirious, constantly moving about the bed, picking the bedclothes, muttering and pointing to imaginary objects. The temperature was 101° F., pulse 135, respirations 32, but irregular. There was no vomiting. There was retention of urine. Three minims of the hypodermic solution of morphia were injected, and two hours later, a similar dose. Next day she was conscious, complained of thirst, took milk, but her pupils were still dilated, and her mouth was dry. Her temperature was 103° F. Three days later her temperature became normal. Her pupils, however, were still dilated a week after her admission to the hospital, and she was discharged well on the twelfth day. Purjesz relates a similar attempt at suicide by "eye-drops," but the quantity taken was only nine-tenths of a grain. Pilocarpin hypodermically was the antidote used.[6] In 1872, at the Manchester Assizes, an inquiry was held before the Grand Jury as to a charge against a nurse named Steele for having maliciously put atropia into milk, from drinking which the resident surgeon of the workhouse died and two other persons were poisonously affected. Madame Bianchini was tried and convicted by the Seine Assizes, held at Paris in March 1899, of having attempted the life of

[1] *B. M. J.*, vol. i. 1900, p. 632.
[2] Idem, vol. i. 1897, p. 1219.
[3] Idem, 1881, p. 639.
[4] Idem, p. 594.
[5] *The Lancet*, vol. ii. 1889, p. 1003.
[6] Pester, *Med. Chir. Presse*, 1880; and *B. M. J.*, vol. i. 1881, p. 300.

her husband by administering to him atropia. From the evidence it appeared that she obtained the drug by means of forged prescriptions.

Symptoms.—These are giddiness, drowsiness, confusion of thought, great thirst and dryness of mouth and throat; indistinct articulation and difficulty of swallowing, for the same reason; talkative, chattering, active, semi-wakeful delirium, in which the patient seems to live in a world by himself; sometimes the delirium is turbulent and the patient violent; the face is rosy and flushed; *the pupils are widely dilated and immobile;* and the temperature of the body is above normal. In cases which end fatally, the drowsiness lapses into deep sleep, then stupor, during which the face takes on a livid appearance; finally there are convulsions, and death.

Post-Mortem Appearances.—Careful watch should be paid to the contents of stomach for portions of berries or seeds. The post-mortem signs are generally those of asphyxia.

Fatal Dose.—An injection *per rectum* of a decoction of 80 grains of the root, one of a drachm of the extract, and of an internal dose of a like quantity of the liniment have proved fatal. Death has occurred from the external application of a belladonna plaster to a sensitive surface.[1] Two grains of atropia have killed. Recoveries have followed, however, after half an ounce of the liniment (*vide ante*), after 8 to 12 grains of extract in a child of 2 to 3 years;[2] and from doses of $3\frac{1}{2}$, 4, and $5\frac{1}{2}$ grains of atropia respectively. An ointment containing 0·21 grammes of atropine applied to the abraded skin caused death.[3]

Treatment.—Use of siphon-tube with free lavage of stomach; emetics, if tube not convenient; tea, coffee, or infusion of tannin, or solutions of tannic acid; hypodermic injections of pilocarpine hydrochlorate—$\frac{1}{3}$ of a grain—or of morphia.

Chemical Analysis.—It is necessary to separate out the alkaloid by Stas' or Dragendorff's process (*q. v.*). But before this, a drop of the filtered vomit or stomach-contents may be instilled into the eye of an animal, to see if pupillary dilatation is produced. Chemical tests of themselves are not reliable.

Belonging to the same natural order are other poisonous plants, viz.: *Datura stramonium* (or Thorn-Apple), and other Daturas; *Hyoscyamus niger* (or Henbane); *Solanum tuberosum* or the common potato, and other Solanums. The *Datura alba* and *D. fastuosa* are common toxic agents in Indian criminal jurisprudence, for a full account of which the reader is referred to Chevers' "Medical Jurisprudence for India." On general lines, the symptoms of the above are identical with those of Atropia. An interesting case occurring in this country is recorded by Taylor[4] in which three persons suffered from the toxic effects of Stramonium which was accidentally present in a mixture of dried herbs which had been put into broth. Taylor found two unmistakable portions of the leaf, two buds, and the corolla of the Stramonium plant in some of the remaining dried herbs,

1 Woodman and Tidy, "Med. Jurisp.," p. 410.
2 *New York Journal of Med.*, Sept. 1845, page 182.
3 Ploss, *Zeits. f. Chir.*, 1863.
4 *B. M. J.*, vol. i. 1882, p. 538.

and from an infusion of these in warm water was obtained a solution which, on application to his own eye, rapidly and fully dilated the pupil. The persons recovered.

Aconite.

(*Aconitum Napellus*, or Monkshood, *Aconitum ferox*, and others.) Nat. Ord. = Ranunculaceæ. *Aconitum napellus*—monkshood—which is indigenous in this country in gardens, grows from a height of two feet upwards, with spikes of blue flowers, each flower being not unlike the cowl of a monk; hence its name. The *A. ferox* grows in the Himalayas, and is even more deadly in its effects than the former. All parts of these plants are poisonous—root, stem, leaves, flowers, and seeds. The root is the part which has most commonly given rise to poisoning, being accidentally mistaken for the root of the horse-radish. It is short and clumpy, not unlike a carrot in shape, or conical in form, throwing off a number of curly fibres, and is nut-brown in colour.

The comparative differences between these roots are presented in tabular form.

CHARACTERISTICS OF

Aconite Root.	*Horse-Radish Root.*
1. Short, carrot-like, tapering.	1. Long and cylindrical, not tapering.
2. Gives off curly fibres.	2. Gives off straight fibres.
3. White when cut, it slowly reddens.	3. White when cut, and remains so for an indefinite period.
4. When tasted, it produces tingling and numbness of tongue, mouth, and lips.	4. When tasted, is hot and bitter, but does not produce numbness.
5. Scrapings of root are friable and succulent.	5. Scrapings are tough and stringy.

From the fresh leaves and flowering tops an extract is made, and from the root a tincture and liniment, as well as the alkaloid Aconitia or Aconitin are obtained.

Aconitin is usually a white amorphous powder, but in Morson's preparation—pseudaconitin or Nepalin—it is crystalline. It is not altered on exposure to air, melts in about 150 parts of cold water, about 50 of boiling water, and in about 750–800 of ether. It is freely soluble in alcohol, chloroform, or benzole. Its salts are also freely soluble in water and alcohol, but not in ether. When the alkaloid is heated on a porcelain spatula, it melts at 140° F. into a yellow liquid, then gives off light fumes or vapour, becomes carbonaceous, and ultimately disappears leaving no residue.

Commercial aconitia varies in strength, and according to Murrel[1] is probably constituted of a mixture of alkaloids. English aconitia is much stronger than the German, the French kind being intermediate in strength. By reason of this variability in strength accidental toxic effects have been produced. Plügge and Huisinga record a case in which a patient was killed by a chemist substituting Petit's nitrate for Friedlander's preparation.[2] Busscher and Desnos record other cases.

[1] *B. M. J.*, vol. i. 1882, p. 555.
[2] *Berl. klin. Woch.*, 1882; *Arch. der Pharm.*, 1882.

Symptoms.—After a poisonous dose, the first notable symptom is the burning and numbness of mouth and throat; then follows pain in stomach, nausea, vomiting; the numbness extends over the body and limbs; the patient complains of the skin of his face feeling as if drawn, of a feeling of constriction in throat and of inability to swallow; there are great restlessness and prostration, and feebleness of muscular power; symptoms of shock supervene, with delirium and unconsciousness; convulsions usually precede death. In the Poplar cases, the pupils were dilated. Springmühl gives a very graphic account of a case of suicidal poisoning by an analytical chemist at Breslau who took 8 grains of Merck's aconitin.[1] Baker narrates the symptoms in four boys and a girl which followed the eating of a piece of aconite root, but all of whom recovered.[2] The matron of a workhouse died in four hours from the effects of three teaspoonfuls of Fleming's tincture. Her pupils were much dilated. Digitalis hypodermically, inhalations of ammonia, injections of brandy, and artificial respiration for two hours failed to avert the fatal issue. Another lady, who took some of the medicine for a headache, was very ill, but she recovered.[3] Reichert gives an analysis of the treatment of forty-one cases of poisoning by this drug, and after discussing the various antidotal remedies which had been used speaks favourably of the use of amyl-nitrite and strychnia, the former by inhalation, the latter subcutaneously.[4]

The *symptoms* may be stated chronologically as follows. Their onset appears from a few minutes to an hour after taking the poison: (1) numbness, burning, and tingling of mouth and throat; (2) feeling of constriction and burning in throat; (3) severe pain and tenderness in stomach; (4) nausea and vomiting; (5) numbness, loss of power, and pain in the limbs; (6) giddiness, singing in the ears, deafness, loss of vision; (7) indistinct articulation, and ultimate loss of power of speech; (8) unconsciousness, convulsive gasps, or convulsions; (9) dilatation or contraction of pupils.

The only case on record of trial for homicidal poisoning by the alkaloid is that of R. *v.* Lamson which was tried before Mr. Justice Hawkins and a jury at the Central Criminal Court on March 16 and 17, 1882. The prisoner—a medical practitioner—while visiting his brother-in-law, a boy at Blenheim House School, Wimbledon, administered the poison to him in a gelatine capsule, into which he ostensibly put some sugar. The prisoner left the house within five minutes after. The boy took ill within half-an-hour after swallowing the capsule, and died in about $3\frac{1}{2}$ hours after the onset of the symptoms. Stevenson and Dupré isolated the alkaloid from the viscera, as proved by physiological tests performed by Stevenson upon himself and upon animals. Purchase of the alkaloid by the prisoner was proved in evidence. He was condemned to death. Poisoning is relatively more common from accident than from suicide or homicide. M'Whannell[5] records a case of fatal result from one ounce of the liniment. We are acquainted with the facts of a case where a man swallowed shortly after a hearty

[1] *B. M. J.*, vol. i. 1882, p. 803.
[2] Idem, vol. ii. 1882, p. 1039.
[3] Idem, vol. i. 1881, p. 64.
[4] *Phil. Med. Times*, Nov. 19, 1881.
[5] *B. M. J.*, vol. ii. 1890, p. 791.

I Refer to Sir W. T. Gairdner's experience
of poisonous effects from external
use of a liniment containing aconite,
Belladonna & opium ([illegible])

mid-day meal half an ounce of A.B.C. liniment, and although the symptoms of poisoning did not actively supervene for about one hour after and he eventually recovered, his life was in great danger for some hours. Treatment had, however, been promptly and energetically applied.

Post-Mortem Appearances.—Those found in the case narrated by Springmühl already described, may be taken as fairly typical. They were as follows: mucous membrane of mouth pale; congestion or engorgement of brain, and lungs; inflammation of stomach and congestion of mucous membrane; and congestion of liver and kidneys. These, it will be noted, are not different from those of other irritant poisons of a similar kind.

Treatment.—Use of siphon-tube and free lavage of stomach with animal charcoal suspended in water; or emetics; administration of stimulants hypodermically or *per rectum*, and restoration and maintenance of animal heat. Some have recommended hypodermic injection of strychnia and inhalations of amyl nitrite.

Fatal Doses.—About one drachm of the root, four grains of the extract, and 25 drops of Fleming's tincture.[1] Of the alkaloid $\frac{1}{16}$ of a grain killed a medical man in Holland (Desnos). Recovery, however, has followed two teaspoonful and tablespoonful doses respectively of the tincture, and over two ounces of the liniment.

Fatal Period.—The shortest is three-quarters of an hour (case of Hunt from about one ounce of tincture);[2] the longest, 20 hours; the average, about 8 hours.

Chemical Analysis.—The alkaloid is separated from the stomach-washings or stomach-contents by the process for extraction of alkaloids, and after isolation, is tested by its effect upon the tongue, and upon mice by injection. According to Stevenson $\frac{1}{2000}$ of a grain of English aconitin may be so detected.

Strychnia ($C_{21}H_{22}N_2O_2$).

(*Strychnos nux vomica*, *Strychnos Ignatii.*) Nat. Ord. = Loganiaceæ. — From the seeds of *S. nux vomica* an officinal tincture and extract are prepared for medicinal purposes. The seeds are flattish, nearly round, less than an inch in diameter, slightly convex on one side and concave on the other, and are covered by fine short, silky, yellowish-grey hairs. They are very hard, and when a small portion is chewed an intensely bitter taste is experienced in the mouth. From this seed the alkaloids strychnia, brucia, and igasuria are obtained, as also from the *S. Ignatii.* The alkaloid strychnia, first isolated by Pelletier and Caventou, in 1818, is found in commerce in the crystalline form as pearly scales, octohedra with rhombic bases, or more commonly as four-sided prisms. It has an intensely bitter taste—one grain will impart to a gallon of water (1 in 70,000) a perceptible bitterness. It forms salts with the acids, sulphuric, hydrochloric, acetic, and others, the acetate being the salt most commonly used, probably by reason of its greater solubility in

[1] *Amer. Med. Monthly*, Mar. 1854, p. 223.
[2] Taylor, "Med. Jurisp.," vol. i. p. 427.

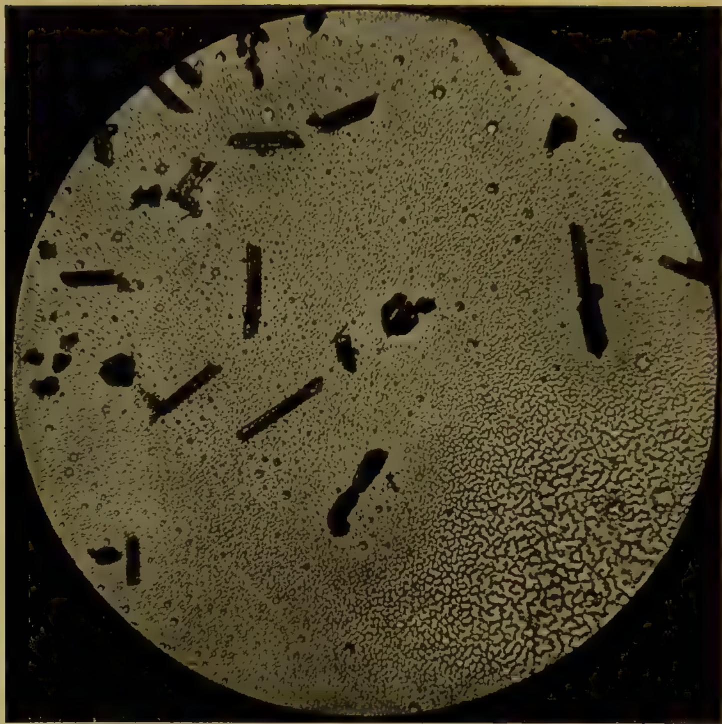

FIG. 105.—Photo-micrograph of crystals of Strychnia obtained from Nux Vomica. × 50 diameters. (Author.)

FIG. 106.—Photo-micrograph of feathery crystals of Strychnia. × 500 diameters. (Author.)

13 read prosthotonus

water and alcohol. One grain of the alkaloid itself dissolves in 7000 parts of cold water at 16° C., and in 2500 of water at 100° C. The salts of the alkaloid are used in different vermin-killers mixed with colouring materials as Prussian blue, indigo, or soot. These are called Battle's, Butler's, Gibson's, Marsden's and Barber's Vermin Killers and Miller's Rat Powder, and all contain varying percentages of the poison, from 23 per cent. downwards. By the sale of these, strychnia is put within reach of the public.

Symptoms.—When a poisonous dose has been swallowed, the following symptoms appear after an interval which may vary from a few minutes up to one hour. An intensely bitter taste is perceived in the mouth; soon thereafter comes on a sensation of suffocation, accompanied by jerking or twitching of the muscles of the neck, body, and limbs, followed by severe tetanic convulsion of all the muscles of the body. During this state the body becomes stiff and rigid, so that the body is thrown into the form of an arch, only the back of the head and the heels touching the bed or ground—the condition known as opisthotonos. In some cases the body-curve is in the opposite direction, called pro[illegible]sthotonos, or it may be laterally curved, pleurosthotonos. Owing to the tetanic contraction of the thoracic muscles breathing becomes difficult and imperfect, and the face in consequence becomes more or less cyanosed. Owing to the contraction of the muscles at the angles of the mouth *risus sardonicus* is produced, the lower jaw becomes firmly shut or fixed by the contracted condition of the masseters, the fingers are clenched in the palms of the hand, the feet arched inwards, and the eyes staring and wild-looking. This so-called spasm or fit lasts from half a minute to two minutes, and then there is a remission of the symptoms. During all the time of the spasm the sufferer is in complete possession of his senses, and he is apt to complain bitterly of the insufferable pain. During the remission he lies in a calm but weakened condition, and he may fall asleep. During the convulsive seizure the pupils become dilated, and during the period of remission they resume their normal condition, which, relative to the former state, appears to be one of contraction. After a variable interval, depending upon the severity of the toxic effects and often as the result of a very trivial cause—such as a person walking across the floor, a touch, or even a draught of cold air—another attack similar to the first comes on; and feeling it impending, the person may ask to be firmly held or rubbed. In cases going on to a fatal issue the intervals of remission are short, in less severe cases they may be longer. Death usually happens either during a spasm from asphyxia induced by the fixation of the chest walls, or from exhaustion from the repetition of the attacks. It may follow, therefore, very shortly after the spasms appear—almost at once—or it may be delayed for some hours. In the trial of Palmer for the poisoning of John Parsons Cooke, the question arose as to the possibility of idiopathic tetanus being mistaken for strychnia poisoning. In tetanus or lockjaw, fixation of the lower jaw is one of the earliest and most prominent symptoms—hence its name,—but in strychnia poisoning it is only a part of the general tetanic contraction of the bodily muscles, and passes off with the muscular relaxation during the period of remission.

Indeed there is no other set of phenomena, from disease or poison, which is exactly comparable to that which follows the absorption of strychnia in the body. The symptoms appear even if the poison is applied externally and is absorbed. But certain cases very closely simulate poisoning by strychnia.

Dixon has reported a case of intermeningeal spinal hæmorrhage —ascertained on post-mortem examination—which by reason of the similarity of the symptoms to strychnia poisoning compelled him to decline to grant a certificate of death without a post-mortem examination. The patient, a tall and very powerful man of forty-nine years of age, who had previously enjoyed uniformly good health but who was somewhat intemperate, had been suddenly seized with violent tetanoid convulsions about half-an-hour after taking tea in the evening. These convulsive seizures continued to recur at short intervals. During each paroxysm the body became completely extended and remained so for a short time; this was followed by comparative relaxation, which however was again succeeded by another spasm. The man was never unconscious; he screamed with the pain caused by the great contraction of the muscles; when anything was put in his mouth the jaw contracted forcibly upon it, and when swallowing was successful, it happened in spasmodic gulps. During a spasm the pupils were dilated, but not insensible to stimulus. He died in less than two hours from the onset of his illness. On post-mortem examination the arachnoid cavity of the spinal canal was found filled with black coagulated blood, and this was believed to be sufficient to account for the symptoms and the death. The stomach and portions of viscera were removed, but nothing is said in the report respecting whether or not they were subjected to analysis.[1]

In one case[2] the application of $\frac{1}{12}$ of a grain of strychnia to the eye produced toxic effects in less than three or four minutes. Gorochofzeff of Orenburg states that the toxic effects of strychnia are more marked when it is introduced into the mouth only than when into the stomach; for example, a dog whose œsophagus was ligatured, and into whose mouth half a grain of the sulphate was put, died in four minutes; while another, which was made to swallow a similar dose, did not die till the end of fifty minutes. He asserts further that he does not think that this rapidly fatal result is brought about by absorption of the poison from the mouth, as in such cases the poison could not be detected in the blood. This latter view, however, does not meet with general acceptance.

The period of onset of the symptoms varies, as has been said, in different cases, depending upon the quantity and form of the poison exhibited, and to some extent, also, upon the condition of the individual. In the case of Madame Merghelynk in 1870, they came on *almost immediately*.[3] In a case where a man on the hunt for pheasants' eggs picked up a hen's egg which he sucked, symptoms of strychnia poisoning[4] showed in *four or five minutes* after. In the

[1] *The Lancet*, vol. i. 1879, p. 333.
[2] *Amer. Jour. Med. Science*, Oct. 1861, p. 573.
[3] Taylor, "Med. Jurisp."
[4] *The Lancet*, vol. ii. 1889, p. 951.

victim of Dove they developed in *fifteen minutes;* in Cooke, the victim of Palmer, in about *one hour;* in another case, in a like period;[1] and in another, in *two and a half hours.*[2] In a case of poisoning by 6 drachms of tincture of nux vomica, the symptoms "quickly developed."[3] Strychnia poisoning may arise from mistakes in prescriptions by chemists.[4] In this case, two persons died from strychnia having in some way got into phenacetine. In Partick near Glasgow, a similar mishap occurred owing to strychnia having been given in mistake for another medicine. Ogilvie narrates a case of accidental poisoning in which an old man and his wife, after each had taken a powder administered by their daughter, developed symptoms of strychnia poisoning. The man died, but the woman recovered. After the post-mortem examination of the body of the man, a "large quantity" of strychnia was found by chemical analysis in the stomach.[5] At the inquest, the chemist gave evidence that the powders he supplied contained calomel and nothing else. It appears, however, that the daughter had been housekeeper to a man who was in the habit of getting calomel powders from this chemist, that on the day she left for home he had given her what he believed to be one of the calomel powders, but had by accident given her instead a paper containing the remains of a small quantity of strychnia which he had bought four years before from a chemist for the purpose of killing a dog. Just a day or two before his housekeeper left his house he had put this packet into his vest pocket, and it was this packet which he had unfortunately given to his housekeeper—the daughter of these old people—in mistake for a calomel powder. The jury returned a verdict in accordance with the evidence.[6]

Strychnia in solution may be accidentally taken, as in the case above narrated of nux vomica poisoning. It is usually taken suicidally in the form of vermin-killers.[7] Homicidal administration has given rise to some well-known cases. Among the chief are those of William Palmer, a medical practitioner, who was tried at the Central Criminal Court, London, May 1856; of William Dove, for the murder of his wife, tried at Leeds, July 1856; of Silas Barlow, for the murder of his mistress, tried at the Central Criminal Court, London, November 1876. In later years, George Horton was tried at the Derby Assizes, May 1889, for the murder of his daughter by strychnia, the poison having been given in the form of vermin-killer; $\frac{8}{10}$ of a grain of the poison being found in the body of the victim; and Walter Horsford, for the murder by strychnia of Mrs. Holmes, at the Huntingdon County Assizes, June 1898, the poison given being a salt of strychnia in the form of a powder. The quantity of the poison found in the body of deceased by the analysts Knight and Dr. Stevenson amounted in all to 6·54 grains. To these must be added the case of Thomas Neill Cream, a medical man, for the murder of four women and the attempted murder of a fifth by strychnia, which was tried at the Central Criminal Court, London.

[1] *B. M. J.*, vol. ii. 1900, p. 1312.
[2] *Amer. Jour. Med. Sci.*, Ap. 1848, p. 592.
[3] *B. M. J.*, vol. ii. 1899, p. 10.
[4] *The Lancet*, vol. i. 1896, p. 135.
[5] *B. M. J.*, vol. i. 1884, p. 1251.
[6] Idem, pp. 1010 and 1101.
[7] *The Lancet*, vol. ii. 1889, p. 166; idem, vol. ii. 1889, p. 643.

Post-Mortem Appearances.—In several cases, prolongation of cadaveric rigidity has been a noteworthy appearance. The body of John Parsons Cooke — Palmer's victim — was "much stiffer than bodies usually are five or six days after death—the muscles strongly contracted and thrown out, and the hands stiff and firmly closed" according to the evidence of Dr. Harland, who made the post-mortem examination of the body. Dr. Stevenson, in the trial of Walter Horsford, stated that the legs and fingers of the deceased woman were rigid at the time of exhumation of the body twelve days after death, and that he had seen the same rigidity in the body of Matilda Clover—one of Cream's victims. Hollis records[1] the p.-m. appearances found on the body of a child of four years who had died from the accidental administration of liquor strychniæ instead of cough mixture. The body on being exhumed twenty-three days after burial and twenty-seven days after death, showed the fingers of the hands to be tightly clenched over the thumbs, the feet to be inverted and arched, and rigidity generally to be well marked. Strychnia was found on analysis in the viscera. But in other cases, such abnormal duration of rigidity is not found. The reason for these different appearances is probably to be found, at least partly, in the period of time which elapses between the onset of the convulsive seizures and death. If it be short—and assuming that the individual has before the administration of poison been in good health—the muscular irritability will not have been exhausted, and thus the period of *rigor mortis* will be longer than if the time be long and the muscular irritability exhausted by the violent tetanic contractions which the muscles have undergone. But it would appear from certain indications as if the phenomenon was also in part due to the specific action of this particular poison.

The most constant appearances of the internal organs are as follow: engorgement of lungs; fluidity and dark colour of the blood; engorgement of blood-vessels of brain and spinal cord; the condition of the right heart with respect to large amounts of blood in its respective cavities. These appearances indicate death by comato-asphyxia. The stomach but rarely presents any unusual appearance. Some observers, however, have stated that congestion of the mucous membrane is present.

Treatment.—Chloroform ought to be administered as soon as possible in view of the fact that the convulsive seizures are induced by almost any treatment of the patient, such as hypodermic injection or the administration of an enema. As soon as the person is under its influence, the siphon-tube ought to be passed into the stomach and that organ freely washed out either with water simply, or with water in which animal charcoal or tannin is suspended. The administration of chloroform, moreover, ought to be continued for hours if need be, so long as the seizures threaten to return. In the unavoidable absence of chloroform, a handy emetic ought to be given, either preceded or followed (preferably the former) by the administration of chloral hypodermically, *per rectum*, or by the mouth. Where death is threatened from arrest of respiration artificial respiration may be tried, but this, if chloroform is not used, will be a difficult if not

[1] *B. M. J.*, vol. ii. 1901, p. 618.

ineffective operation, because of the fixed and rigid condition of the muscles of arms and chest. Other symptoms must be treated as they arise.

Fatal Dose.—Although alarming symptoms have on more than one occasion been occasioned by $\frac{1}{12}$ of a grain, a *quarter of a grain* is the smallest fatal dose which has been recorded.[1] This was in the case of Agnes Sennett or French, a patient in the Glasgow Royal Infirmary, who in Sept. 1845 swallowed a pill which contained by prescription that amount of the drug and which had been prepared for a paralytic patient. The symptoms came on in three-quarters of an hour after, and she died in $1\frac{1}{4}$ hours. Half a grain has also produced fatal results.[2] Recoveries after prompt treatment have, however, followed large doses; for example, one in which 20 grains were taken[3] and another, in which 40 grains were swallowed.[4] Other cases of recovery from large doses are also recorded.

Fatal Period.—Death may happen almost immediately. This result happened in the case of a druggist who took $1\frac{5}{8}$ grains, along with nux vomica powder, in addition. Life may, however, be prolonged for hours after the onset of symptoms. Paley records a case in which death did not follow until 5 hours;[5] and in at least other four recorded cases, it did not happen till 6 hours after.

Chemical Analysis.—Of all the alkaloids, strychnia is perhaps the most easily detected, because of its less liability to decomposition in the animal tissues, of its markedly bitter taste, and of its chemical reactions. It has been discovered in the bodies of those poisoned months after interment. The stomach-washings, vomited matter, contents of stomach, or finely pulped bodily organs are treated by strong alcohol and acetic acid, the latter in sufficient amount to give the whole a distinct acid reaction. The mixture is kept hot for two or three hours, then strained through a fine cloth, the alcohol nearly all distilled from the filtrate, and the remainder evaporated on a water-bath at about 70° C., to nearly dryness. The residue now consists of the acetate of strychnia and organic matter. This is then stirred with a little distilled water acidified by acetic acid, filtered, the filter washed with a little water, and the filtrate put into a test-tube, bottle, or small separator; slight excess of solution of caustic potash or soda is now added, which throws the alkaloid out of solution, and pure chloroform or a mixture of chloroform and ether, in volume larger than that of the solution, is at once added, and the whole vigorously shaken for some minutes. When the fluids have separated and if a separator has been used, the chloroform layer which is lowermost is run off, or if a test-tube or bottle has been used, the upper aqueous layer is pipetted off; in either case, the chloroform fluid is transferred into a watch-glass. The aqueous alkaline fluid is again treated as before with fresh chloroform, and, after separation, the chloroform is added to the first chloroform. The chloroform extract, which contains the strychnia, is now permitted

[1] Evidence of Dr. Corbett, in trial of Palmer.
[2] Warner, "Poisoning by Strychnia," p. 138.
[3] *Buff. Med. and Surg. Jour.*, Nov. 1866, p. 135 (quoted by Wormley, *op. cit.* p. 543).
[4] *Med. Gaz.*, Sept. 21, 1865, p. 267.
[5] *Brit. and For. Med.-Chir. Rev.*, Oct. 1860, p. 382.

to evaporate spontaneously to dryness under cover. A portion of the dried residue may now be transferred to a clean porcelain slab and tested by the colour and other reactions. The remainder, if impure, must be re-treated with distilled water and acetic acid, with potash, and with the chloroform solvent as before, in order to rid it of organic matter. If the quantity obtained be ponderable, it should then be carefully weighed. The strychnia found after this treatment is composed of varied crystalline forms.

Liquid Tests.—

1. The Colour Test.—If to the crystals be added two drops of strong H_2SO_4, no reaction will happen; but if the edge of the solution be touched with a tiny portion of manganese peroxide or potassium bichromate in the solid form, or with a drop of a strong solution of the latter, a beautiful deep blue colour will form at the point of contact which will rapidly change into purple, crimson, and red, and then slowly fade away. This play of colours is characteristic of strychnia, and can be perceived with the 1–10,000th of a grain of the poison.

2. The Physiological Test.—This was originated by Marshall Hall, and was based on the sensitiveness of frogs to the action of strychnia. He advised that a fresh frog be immersed in the solution suspected to contain strychnia, the presence of the strychnia in the fluid being shown by the development, sooner or later, of tetanic convulsions in the animal. Harley proposed a modification of the test by injecting some of the solution into the thoracic or abdominal cavity of the animal. Hall claimed that by his method the 1–5000th of a grain could be detected, and Harley, by his method the 1–16,000th part of a grain.

3. Taste Test.—This should be performed with great caution on the residue obtained from the foregoing process. It is of value in demonstrating the presence or absence of a markedly bitter taste.

Digitalis Purpurea (Foxglove).

Nat. Ord. = Scrophulariaceæ.—This plant, which is familiar in the woods, by the roadsides, and in gardens owing to its beautiful spike of purple, dark-red, or white bells, is poisonous. Its leaves, root, and seeds contain the following toxic glucosides, viz.: digitalin ($C_{54}H_{84}O_{27}$), digitoxin, digitalein, and digitonin, and other principles. The leaf is large, ovate, crenate in shape, narrowed at its base and downy, especially on its under surface. It is of a dull-green colour. The root is composed of many long slender rootlets. From the leaves, especially, is obtained the glucoside digitalin, which when pure, consists of fine white acicular crystals, has no odour, and possesses a bitter taste. It and digitoxin are the principal poisonous constituents. Digitalin is a cumulative poison. Many cases of poisoning have resulted from the leaves having been eaten in mistake for borage or other plant, and it has been used homicidally at least upon one occasion, viz.: in the notorious case of the widow De Pauw, who was poisoned by the homœopath, Conty de la Pommerais, as recorded by Tardieu.

Symptoms.—These are nausea, vomiting, which may not however come on for two or three hours after the taking of the poison, followed by abdominal pains, and, perhaps, diarrhœa. The pulse becomes remarkably slowed; in one recorded case it fell to 25 beats per minute. Consequent upon this condition of the heart, there is a feeling of faintness and præcordial oppression, the respiration becomes

slow and sighing, the patient becomes drowsy, which last state may gradually deepen into coma; convulsions may precede death.

Fatal Dose.—Is very uncertain. Mawer[1] states that a woman who took 56 granules of Homolle's preparation of digitalin, equivalent to a dose of 84 grains of dried leaf, recovered. Nine drachms of the tincture has killed in one case, and thirty-eight grains of the powdered leaves in another.

Post-Mortem Appearances.—Are not characteristic. Where the leaves have been eaten, or the powdered leaves taken in infusion, search should be made for fragments.

Chemical Analysis.—For the discovery of the glucosides, the Stas-Otto, or Dragendorff process of separation is necessary. An alcoholic extract is made of the material to be examined, the alcohol having been acidulated with acetic acid. This is then dissolved, after concentration into a syrupy consistence, with water rendered feebly acid by acetic acid, then shaken up with petroleum ether to remove impurities, then with benzene, which will dissolve out digitalein, and next with chloroform, which dissolves the digitalin and digitoxin. To identify these is next necessary. The only fairly reliable way is by physiologically testing the residues by injecting minute portions into a frog. The method adopted by Tardieu in the Pommerais case, where it was suspected that digitalin was the poison used, was to expose the hearts of three frogs by opening the thoracic cavities. No. 1 was left alone, except that the heart was kept moist; into the pleura of No. 2, a definite known amount of digitalin (6 drops of a solution containing one of digitalin in 500) was injected; and into the pleura of No. 3, some of the suspected solution of the extract from the body. The number of contractions of the heart was then counted in each. In the above case, the heart of No. 1 beat 42 times per minute at the end of six minutes, and 36 at the end of 31 minutes; that of No. 2, 20 and 0 at the same respective periods of time; and that of No. 3, 26 and 0 respectively at the like periods; the last two had obviously died before the end of the second period. From this comparative method of examination, it was demonstrated that the suspected material contained a cardiac poison. Brouardel thinks that doubt exists as to whether the poison was digitalin. At the time of the trial of Pommerais, Dr. Hébert, pharmacien of the Hôtel Dieu, showed that in decomposing organic substances toxic principles existed which produce effects upon the heart identical to those from digitalis.[2]

[1] *The Lancet*, 1880. [2] Ibid., vol. i. 1889, p. 763.

CHAPTER IV.

VEGETABLE POISONS AND SEPARATION OF ALKALOIDS.

The method first proposed for separating alkaloids of vegetable poisons from mixtures containing organic matter, such as vomited material, the contents of the stomach, or from the organs of the body was that by Stas.[1] This consisted in extracting them by strong alcohol acidulated with tartaric acid, filtering and concentrating the alcoholic extract, neutralising it with soda, shaking up the mixture with ether, pipetting off the ethereal extract, allowing it thereafter to evaporate spontaneously, and thus obtaining the alkaloid in the residue. To this original process various additions in respect of solvents and chemical reagents have been made from time to time by different chemists as Selmi, Prollin, Thomas, Erdmann and von Ushlar, and others, until Dragendorff published in 1876 his elaborate system of separating by different solvents[2] alkaloids and glucosides, and other active animal and vegetable principles. In this system, however, are utilised the principles of processes formerly proposed. The main principles of this system are the uses of different solvents in acid and alkaline media.

The organic substance to be examined—vomited material or bodily organs—must undergo certain preliminary treatment, viz.: (1) it must be as finely divided as possible; (2) digested for some hours in water at a temperature of 40–50° C., and the whole made distinctly acid with sulphuric acid; (3) filtered; (4) the extraction and filtration repeated two or three times; (5) the filtrates united. The combined extract is next evaporated to a syrupy consistence on the water-bath, is then mixed with two or three times its bulk of alcohol, is allowed to macerate for 24–36 hours at about 34° C., is then permitted to cool, and last of all is filtered, the residue on the filter being washed with 70 per cent. alcohol. The alcohol is then distilled from the filtrate, and the aqueous residue which remains is diluted with water and filtered. The material is now ready for the use of the solvents which ought to be used in the following order. When, however, from the symptoms exhibited during life a particular poison is suspected, the operation may be abbreviated by the use of the most suitable solvent of the alkaloid suspected.

The solvents are as follow: *first*, in the *acid aqueous fluid*,

(*a*) *Petroleum ether*.

This dissolves out *picric acid*, *camphor and other ethereal oils*, carbolic acid, etc.

[1] *Annal. d. Chem. and Pharm.* vol. 84, p. 379.

[2] *Gerichtlich-chemische Ermittelung von Giften.*

"on the active Principle of Poisoned Spears. [illegible]

(*b*) *Benzene.*

This dissolves out *thein*, *digitalin*, *cantharidin*, *colchicin*, etc.

(*c*) *Chloroform.*

This dissolves out narcein, papaverin, cinchonin, etc.

Then the same solvents are used after the aqueous solution has been made *alkaline* with a solution of caustic potash or soda, or with ammonia.

(*a*) *Petroleum ether* (cold).

This dissolves out volatile alkaloids and small amounts of fixed alkaloids. A preliminary test of the residue from a small portion of the solvent will make it clear whether volatile alkaloids are present or not. If not, then the solvent and the aqueous solution may be raised to 40° C., and vigorously shaken.

This dissolves out strychnin, brucin, quinin, coniin, anilin, etc.

(*b*) *Benzene.*

This dissolves out strychnin, brucin, aconitin, the opium alkaloids—codein, narcotin, thebain, atropin, physostigmin, etc.

(*c*) *Chloroform.*

This dissolves out morphin, papaverin, narcein, etc.

Then the aqueous alkaline solution is shaken up with—

Amylic Alcohol.

This dissolves out morphin, solanin, salicin, etc.

Last of all the aqueous solution is evaporated to dryness after addition of powdered glass, and mixed with—

Chloroform.

This dissolves out Curarin.

The foregoing, which is but an outline sketch of Dragendorff's method, will give the student who is familiar with chemical manipulation some conception of the mode by which alkaloids are separated.

The Stas-Otto process is based upon the following main principles, viz. (1) that the acid salts of the alkaloids are soluble in water and alcohol; (2) that these and the neutral salts are for the most part insoluble in ether; and (3) that the alkaloids, when precipitated from an acid solution by an alkali or alkaline carbonate, are soluble in ether or amyl-alcohol. The technique of the process is as follows: the suspected substance, having been prepared by being divided finely or mashed into a pulp, is heated at 90° C., and mixed with alcohol, with sufficient tartaric acid added to make the mixture distinctly acid. The whole is then allowed to macerate for a length of time in a closed or nearly closed vessel at a temperature of 70°–75° C. After cooling the liquid is filtered, and the residue on the filter well pressed out, the fluid therefrom being mixed with the filtrate. The residue is again treated with alcohol, and the whole process repeated at least three or four times. The various filtrates are mixed together, filtered, and evaporated *in vacuo* at 35° C. The residual liquid is again filtered through a water-moistened filter to arrest fat, which may further and more completely be removed by shaking up the residual liquid in a separator. The aqueous acid layer being run off, powdered glass is added, and the fluid is evaporated almost to dryness *in vacuo* over sulphuric acid. The residue is then mixed with absolute alcohol and allowed to macerate for at least 24 hours, and, then, is again evaporated as before *in vacuo* at 35° C. This residue is thereafter mixed with water, and an alkaline carbonate is added till the mixture is alkaline. This throws any alkaloid present out of solution. The aqueous alkaline fluid is now shaken up with four times its volume of pure ether, the ethereal layer separated, and allowed to evaporate spontaneously at the ordinary temperature. If any

alkaloid be present, it is left on the evaporating watch-glass as a residue, which may, thereafter, be tested for identification of the alkaloid.

In dealing with certain alkaloids in previous pages, we have sketched in some detail the process to be followed for their isolation, but no one should attempt to detect these, or indeed any poisons in the organs of the body, or in substances which have come from the body, unless they are sufficiently expert in chemical manipulation and technique.

Associated with alkaloids of vegetable origin are certain alkaloidal bodies which are found in the living as well as in the dead body and in decomposing animal matter. These are more commonly called ptomaines, as they were named by Selmi, but chemically, they are identical in many particulars with the alkaloids which have been discussed. For example, like vegetable alkaloids, ptomaines contain nitrogen; they exist in solid and liquid, volatile and non-volatile forms; they are alkaline, unstable bases, and unite with acids to form salts; they each produce definite physiological results when injected into the body of a healthy animal, corresponding in some particulars to those produced by the vegetable alkaloids, and, generally, are precipitated by the same group reagents. To those alkaloidal substances which are produced in the living body by the operations of the organs as the effect of tissue-metabolism, the name "leucomaines" was applied by Gautier. In addition to these alkaloidal bodies, moreover, there are found certain nitrogenous substances, not alkaloids, which have received the name of tox-albumins, or albumoses.

Several ptomaines have already been isolated, as Putrescin ($C_4H_{12}N_2$), Cadaverin ($C_6H_{14}N_2$), Saprin ($C_5H_{16}N_2$), Neuridin ($C_5H_{14}N_2$), Hydrocollin ($C_{11}H_{13}N$), Collidin ($C_8H_{11}N$), Parvolin ($C_8H_{11}N$), and others, which, because of the absence of oxygen in their composition, have been separated into a non-oxygenated group. The first four named have but little toxic effects, whereas hydrocollin or hydro-collidin, which was isolated by Gautier and Etard from decomposing mackerel and horse-flesh, and others as peptotoxin, and mydein of the same group, possess highly toxic properties. Of the oxygenated group may be mentioned Cholin ($C_5H_{15}NO_2$), Neurin ($C_5H_{13}NO$), Muscarin ($C_5H_{10}NO_3$) — which is found not only in *Agaricus muscarius* but also in human flesh—Gadinin ($C_7H_{16}NO_2$), Mytilotoxin ($C_6H_{15}NO_2$)—obtained from poisonous mussels — and others—all of which are extremely poisonous.

Certain of them cause dilatation of the pupil and coma; others, convulsive effects, and others paralyse the action of the heart. It will be thus apparent that without the exercise of the greatest care ptomaines might be mistaken for vegetable alkaloids in the examination of the body after it has undergone putrefaction. Indeed this question arose in the Lamson case, and appeared to constitute the theory of the defence to account for the cause of death of Percy Malcolm John. It was for some time held to be a differentiating feature between ptomaines and vegetable alkaloids that the former reduced *ferri*-cyanide of potassium to the state of *ferro*-cyanide in the presence of a ferric salt, but Brieger traverses that view, and states

that where the reaction does happen, it is only because of impurities present in the ptomaines.[1] Moreover, when one remembers that to obtain a ponderable amount of ptomaine from decomposing animal material it is necessary to operate upon large amounts—often one or two hundredweights—it will be seen how little likely the finding of an alkaloid from a small quantity of stomach-contents or small bulk of bodily organs by the Stas-Otto process will be confounded with ptomaines.[2]

Calabar or Ordeal Bean (*Physostigma Venenosum*).

Nat. Ord. = Leguminosæ.—As the name implies, this bean was used as an ordeal for various purposes among primitive peoples. It is thicker than our own garden bean, measures from one to one and a half inches in length and a half to three-quarters of an inch in width, and weighs from $1\frac{1}{2}$ to 2 drachms. It consists of a shell and kernel, the former hard, brittle, and claret-coloured, the latter being white in colour, but without smell or taste. From the kernel the alkaloid—Physostigmin or Eserin—is obtained, which is now mainly used in ophthalmic practice, but was at one time much used by some in the treatment of tetanus. The alkaloid is either colourless or slightly yellow in colour, has a bitter taste, is slightly soluble in water, but is freely soluble in alcohol, ether, chloroform, or benzol. Physiologically, it contracts the pupil; in a poisonous dose, it causes giddiness, paralysis of voluntary muscles, and muscular twitchings. Death happens from asphyxia, due to paralysis of respiratory muscles.

There is no recorded case of criminal poisoning, but there are several which have arisen from accident. In 1864, about seventy children in Liverpool were seized at the same time with toxic symptoms due to eating the beans which had been thrown out with some rubbish. Only one boy who had eaten six beans died. Of thirteen of the children examined, only one had contracted pupils.[3] In another instance, two children aged three and six respectively who each ate the kernel of one nut recovered.[4]

Cases of poisoning may arise in shipping ports owing to occasional cargoes of beans being imported as ballast. Recently, our attention was drawn to this in the case of one seaport.

Treatment.—Use of siphon-tube; hypodermic injection of atropin, or injection of chloral *per rectum.*

Cannabis Indica or Indian Hemp.

This is used by natives of the Malay peninsula and of parts of the East Indies in the form of haschish, just as opium is among the Chinese, for the purpose of obtaining intoxication of a sensuous character. The drug itself and its preparations are apt to vary in strength.[5] Cases of accidental or suicidal poisoning have been recorded.[6]

[1] *Weitere Untersuchungen über Ptomaine*, Berlin, 1885.
[2] Stevenson, *B. M. J.*, vol. i. 1884, p. 1136.
[3] Cameron, *Med. Gaz.*, Oct. 1864, p. 406.
[4] *Edin. Month. Jour.*, 1864, p. 193.
[5] Walker, *B. M. J.*, 1896, vol. ii. p. 1382.
[6] Minter, *B. M. J.*, vol. ii. 1896, p. 1772; idem (Saxby), vol. ii. 1896, p. 1160.

Symptoms.—Giddiness; drowsiness; numbness and sense of loss of power of limbs; anxiety; a sensation as if going mad, or of impending death; feeble but quiet respiration; weak and irregular pulse and faint heart action; dilatation of pupils; deep unconsciousness. In Minter's case, where the dose of the tincture was 10 minims three times daily, the toxic symptoms only appeared after the drug had been taken regularly for twenty-four days. This patient said he felt he was mad, that he could see and hear one minute but could not the next; he was very restless and had a distressing sense of impending death. The latter narrated symptoms of the above group were present in the case observed by Saxby, whose patient had taken about two teaspoonfuls of the B. P. tincture.

Treatment.—Injection, hypodermically, of strychnia sulphate, where the patient is deeply unconscious; stimulants *per rectum*, or by mouth if patient is able to swallow; otherwise, the general line of treatment ought to be like that for other narcotics.

Cocaine, Benzoyle Methyl-ecgonine ($C_{17}H_{21}NO_4$).

Cocaine is the alkaloid of *Erythroxylon coca*, and is a crystalline substance, without colour, having a bitter taste, which leaves behind it a numbness of the tongue and mucous membrane of the mouth. It is but slightly soluble in water. It has the property of de-sensitising the terminal nerves of the part into which it is injected or absorbed, and in a large dose produces paralysing effects upon the central nervous system. When injected for minor operations, such as extraction of teeth, it has produced toxic effects. In some persons the injection hypodermically of the drug has become a confirmed habit. From both of these causes fatal poisonings have resulted.

Symptoms.—Pallor of face; dilatation and immobility of pupils; rapid unconsciousness; convulsions; pulse abnormally rapid at first, rapidly slows down, and becomes intermittent and feeble.

Barratt[1] records a case where a medical man injected hypodermically into his own body, in two doses at an interval of five minutes, 40 minims of a 35 per cent. solution, equal to about 14 grains of cocaine hydrochlorate. Eight minutes after he felt very weak, but was conscious. On examination he was found to be almost pulseless. Ether was injected hypodermically and brandy administered by the mouth on several occasions at short intervals for three hours, on account of the threatened failure of the heart. He never lost consciousness. During these three hours he perspired freely because of the copious draughts of hot weak tea which he drank to allay his great thirst, and he passed about 80 ounces of urine. There was no tendency to convulsions, which is a common feature in such cases. In a few days he was quite well. Vinogradoff[2] gives an account of the post-mortem examination of the body of a young woman who died from the effects of twenty-two grains of cocaine which were administered as rectal injections to produce anæsthesia for a surgical operation in that region. Within a quarter of an hour after the injection she began to suffer from clonic spasms in the limbs and opisthotonos, and became

[1] *B. M. J.*, vol. i. 1896, p. 1032.

[2] *The Lancet*, vol. ii. 1889, p. 656.

cyanosed. Examination of the body revealed fluidity and dark-brown colour of the blood, like that found in potassium chlorate poisoning. The signs of death by asphyxia were also present. This death caused the surgeon who made the mistake in the amount of cocaine injected to commit suicide. Golovkoff[1] relates another case where toxic effects followed the injection for toothache of fifteen minims of a 2 per cent. solution of the hydrochlorate, a similar dose having been injected between three and four hours before. The symptoms were: restlessness, dilatation of pupils, pallor of skin, rapidity of pulse and respiration, shivering, dread of death, and convulsive movements of the limbs. The respirations rose to 200 per minute, and the heart-sounds were audible at a distance of two paces from the patient. Ammonia administered internally and by inhalation had a remarkable restorative effect. In a couple of hours the patient had recovered. Zantchevsky's experiments show that a nearly identical train of symptoms is produced on dogs by this drug, and calculated according to body weight, that the lethal dose for man should be between 20 and 40 grains; and that to produce chronic poisoning a daily injection of four grains should be required.[2]

In chronic poisoning exhibited by habitual users of the drug, in addition to the signs of physical degeneration which are apparent, psychical degeneration, as indicated by moral debasement, is also present. In those persons, complaint is often made of the sensation in the skin as if grains of sand or other particulate bodies were lying in or under it,—a symptom which was first pointed out by Magnan.

Post-Mortem Appearances.—These are negative as indicating the character of the poison. Death being due to asphyxia, the signs of that form of death are likely to be found. Vinogradoff has pointed out (*vide supra*) the fluid character and dark-brown colour of the blood, showing that the poison acts upon that fluid, and that hyperæmia of brain and lungs, and albuminoid degeneration of nerve cells of cerebrum, of the muscular fibres of the heart, of the liver cells, and of the epithelium of the urinary tubules, were also present in the case narrated.

Treatment.—After evacuation of contents of stomach, attention must quickly be paid to the action of the drug upon the heart. Judging from Golovkoff's experience and that of others, ammonia ought to be freely administered in the form of inhalation and also internally. Gooding[3] and Mowat[4] have both reported favourably of its effects. Ether should be injected hypodermically, and brandy may also be freely administered by the mouth if the patient be conscious, and the thirst should be satisfied by copious draughts of hot weak tea. Chloroform ought to be used to overcome convulsions, and artificial respiration for threatened asphyxia.

Fatal Dose.—Two-thirds of a grain killed a woman of seventy-one years of age, and twenty minims of a 4 per cent. solution injected into the urethra has produced the like result.[5] Recovery has fol-

[1] *The Lancet*, vol. ii. 1889, p. 1126.
[2] Barratt, *vide supra*.
[3] *The Lancet*, vol. i. 1888, p. 394.
[4] Idem, vol. ii. 1888, p. 715.
[5] Mathieson, *Dub. Jour. Med. Sc.*, 1895.

lowed, however, the use of larger doses, as in the cases reported by Barratt and others.

Chemical Analysis.—Is not very satisfactory.

Laburnum (*Cytisus Laburnum*).

This gives rise to toxic symptoms when the seeds, bark, or flowers are eaten, as sometimes happens, inadvertently by children. The tree is a common one in gardens, shrubberies, and woods, and may be recognised by its greenish bark, its drooping tassels of yellow flowers, which afterwards develop into bunches of pods. The toxic principle of the bark and pods—Cytisin—belongs to the narcotico-acrid class. Death has resulted in animals and human beings from eating the bark,[1] and in children, the seeds.[2] Two fatal cases in children, aged three and eight years respectively, occurred at Shigshy, Yorkshire, after eating the pods or seeds. The elder child was attacked by vomiting and diarrhœa, pains in the head, and complete prostration, and died fourteen hours after. The younger child vomited, complained also of pain in the head, and became unconscious; for two and a half hours before her death she had convulsions. She died eight hours after beginning of attack. Cytisin was found in the stomach contents of each child.[3] A boy of four years suffered severely from eating some of the flowers. He came home stating that he could not walk, and was sick. He was drowsy, and became cold, his temperature falling later to 93·6° F. His pupils were dilated, but they contracted under a bright light. He recovered.[4]

Symptoms.—Vomiting, purging, great restlessness, then drowsiness, coma, with convulsive twitches, and convulsions; subnormal temperature.

Post-Mortem Appearances. — Dilatation of pupils; clenched jaws; intense inflammation in intestinal tract from lower third of duodenum to lower end of ileum.

Treatment.—Evacuation of stomach-contents; purgatives; stimulants.

Fatal Period.—In eight hours; six days in a child of 5½ years, from seeds; thirteen hours, from bark.

Fatal Dose.—Not well ascertained.

Darnel Grass (*Lolium temulentum*).

Nat. Ord. = Graminaceæ.—Toxic effects have been produced from this plant where persons have partaken of bread baked with wheat the flour of which contained ground darnel seeds. In 1850, it was recorded that thirty persons were seized with symptoms of poisoning after eating such bread, but all recovered.[5] Christison records that eighty persons in Sheffield were similarly attacked, but they also recovered; and he gives another instance, in which a farmer, his wife, and a servant partook of bread made up of flour composed of one part wheat and five parts darnel, from the effects of which the farmer and the servant died.

Symptoms.—Headache; giddiness; vomiting and purging; symptoms not unlike delirium tremens; impaired vision; paralysis; convulsions.

Treatment.—As for any other narcotico-irritant poison.

Colchicum Autumnale or Meadow Saffron.

This plant and the medicinal preparations made therefrom are poisonous. From the seed, bulb, and plant generally, the alkaloids colchicin and colchicein are obtained. The plant is equally fatal to cattle as to human beings. In 1862, Margaret Wilson was convicted of the murder of Mrs. Somers by administering this drug. From the evidence, it would appear as if the prisoner had in the same way caused the death of other three persons. As the active principle of the drug is a common constituent of proprietary preparations for gout, accidental poisonings have frequently occurred.[6]

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[1] *Veterinarian*, vol. lv. p. 92; *The Lancet*, vol. i. 1868, pp. 58, 86.
[2] *B. M. J.*, vol. i. 1870, p. 79 (Wheelhouse).
[3] Ibid., vol. i. 1882, p. 199.
[4] Idem, vol. i. 1883, p. 1117.
[5] *Edin. Month. Jour.*, Aug. 1850, p. 180.
[6] *The Lancet*, vol. i. 1881, p. 368.

"Taxine, the alkaloid of Yew" Thorpe & Stubbs. Proc. Chem Soc. Vol. 18. No 253
p. 123 et seq.

Death of Socrates by Plato – vide paper by Hughes Bennett of Eden →

News
Aug 20: 1909

GLASGOW N

'ARTICK POISONING.

SEVEN BOYS AFFECTED.

LABURNUM DANGERS.

Much excitement was caused in Partick st night when it became known that seven ɔys had been conveyed to the Western ıfirmary suffering from symptoms of poisning.

The youngsters, whose ages range from x to eleven years, had been on one of ose excursions which delight a boy's heart, ıd the presumption is that on their way ɔme they had been tempted and fell to the llurement of the pea-pod-like fruit of the lburnum. Several trees of this species row near Hamilton Crescent, the route to e lads' residences in Clarendon Street and ansfield Street, and from the admission of ne of the boys that they had been eating wee pea shaps off a tree," the laburnum eory has been generally accepted as reonsible for the illnesses.

The first to sicken on reaching home was ames Murphy, residing in Clarendon Street, ıd his condition ultimately

Became so Serious

ıat he was conveyed in an ambulance wagɔn to the Western Infirmary, where it was und that he was suffering from poisoning.

Shortly afterwards David Murphy, a ounger brother, was also seized with the ame symptoms, and he was taken to the nfirmary, to be followed almost immediately y their five companions—Harry M'Kelvie nd John M'Alinden, Clarendon Street, and Bertie Strain, Alex. M'Farlane, and Archiald Core, of Mansfield Street.

All were detained for treatment, and at he infirmary this morning it was stated that hey were progressing favourably, with the xception of the elder boy Murphy, who was he most seriously affected. The boys, it is xpected will be able to be dismissed from he institution during to-day.

"Taxine, the alkaloid of Yew" Thorpe & Stubbs. Proc. Chem Soc. Vol. 18. No 253
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Death of Socrates by Plato – vide paper by Hughes Bennett of Eden →

CYCLING.

WORLD'S CHAMPIONSHIPS.

ENGLISH WHEELERS SUCCESSFUL.

The world's cycling championship meeting was continued at Copenhagen yesterday in boisterous weather. There were, however, about 3,000 spectators.

In addition to the preliminary heats of the 1,000 metres professional championship, the 100 kilometres amateur championship was decided. The title of the latter was held by Leon Meredith, the famous English long-distance cyclist. Meredith had little difficulty in repeating his success. He led from the start, and beat his nearest opponent, Cuzin, of France, by 7min 12sec.

Meredith's time was 1hr 39min 8sec, nearly 10min slower than the time he accomplished at Leipzig last year. At Leipzig, however, the race was decided under more favourable conditions than those which prevailed yesterday. Cuzin's time was 1hr 46min 20sec. Paton, Belgium, was third in 1hr 54min 47sec, and Bijleveldt, of Holland, was fourth.

W. J. Bailey, the one and five miles British N.C.U. champion, won the final of the 1,000 metres amateur championship by half a length from Neumer, of Germany. Bailey's time was 1min 28sec. Schilles, of France, was third, a wheel behind Neumer.

TO-MORROW'S RUNS.

Broomhill—Campsie Glen 3.0
Barony—Lugton 3.0
Clydebank—Impromptu—I.L.P. Hall 3.0
Carlton—Irvine—Suspension Bridge 3.0
Craigpark—Tillitudlum—Craigpark Street 3.0
Caledonian—Strathaven—399 Rutherglen Road 3.0
Douglas—Campsie Glen—Shamrock Street 3.0
Devon—Lochwinnoch—Devon Street 3.15
Empire—Stirling—Cumberland Street 2.45
Future—Mollinsburn .. .. —
Gipsy—Lugton (inter-run with Barony C.C.)—
Queen's Park .. ..
Glasgow—Strathaven—Bridgeton Cross 2.30
Govan United—Crossford—Elder Park 2.45
Govan—Balloch—I.L.P. Hall 2.15
Heeshtie—Dumbarton—87 Old Dalmarnock Road 2.0
Kilbarchan—Rouken Glen—Steeple Square 2.30
Kinning Park—Auchentibber—Town Hall 3.0
Leith—Impromptu—Labour Hall 2.45
Motherwell—Gartcosh—Socialist Institute 2.30
Parkhead—Airdrie—Burgher Street 3.0
St Mark's—Blanefield—Argyle Street 3.15
St George's Co-op.—Langbank—40 Gladstone St. 3.0
Stonehouse—Darvel—New Street 2.45
Springburn—Denny—Fire Station 3.0
Vale of Leven—Maryhill—Tulliechewan—South 2.0
Gate .. ..
Vulcan—Pathhead—Brougham Place 3.0
Victoria—Campsie Glen—Rendezvous 3.0
Windsor—Drymen—Burnbank Gardens 3.0
Wheelers—Balloch—Botanic Gardens 3.15
Westmuir—East Kilbride—Cycle Depot 3.15
3.0

SUNDAY.

Clydebank—Balfron—I.L.P. Hall 10.0
Devon—Bonnyrigg—Devon Street 10.15
Edinburgh—Lauder—Mound 10.0
Glasgow—Linlithgow—George Square 10.0
Govan—Ayr—I.L.P. Hall 10.0
Parkhead—Lochard—Burgher Street 10.15

"Taxine, the alkaloid of Yew" Thorpe & Stubbs. Proc. Chem Soc. Vol. 18. No 253
p. 123 [illegible]

Death of Socrates by Plato - vide paper by Hughes Bennett of Edin →

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PROCEEDINGS

OF THE

CHEMICAL SOCIETY.

EDITED BY THE SECRETARIES.

Vol. 18. No. 253.

Wednesday, May 28th, 1902. Professor MELDOLA, F.R.S., Vice-President, in the Chair.

Messrs. J. W. Peck, J. C. Crocker, and J. Kewley were formally admitted Fellows of the Society.

Certificates were read for the first time in favour of Messrs.:

Edwin T. H. Bucknell, Ebley House, Parsonage St., Dursley, Glos.
Francis E. Francis, 8, Manilla Rd., Clifton, Bristol.
George Paton Pollitt, Ph.D., St. Silas Rd., Blackburn, Lancs.
Harold James Roast, 3, Manor Park Rd., Harlesden, N.W.
Edward J. Wheeler, Albany, State of New York, U.S.A.

Of the following papers, those marked * were read:

*81. "Taxine, the alkaloid of yew." By T. E. Thorpe, C.B., F.R.S., and G. Stubbs.

The investigation has been carried out on autumn-gathered leaves of male and female trees of the species *Taxus Baccata*. The alkaloid was

extracted by digesting the powdered, air-dried leaves with 1 per cent. sulphuric acid for 5 or 6 days. The acid liquid was strained and pressed from the leaves, and at once, without concentration, rendered alkaline and extracted with ether. Taxine was obtained in the form of very fine, glistening particles by crushing down the residue from the ether extract. It gives precipitates with most of the alkaloidal reagents, and colour reactions with strong sulphuric acid alone, and when this reagent is mixed with nitric acid, molybdic acid, or chromic acid.

Taxine is very susceptible to change. At least two substances result from the action of dilute acids upon it, but owing to lack of material the authors have not yet completed their investigation of these products.

Several salts have been prepared and analysed. Two compounds with gold chloride have been obtained which have the formulæ $C_{37}H_{52}NO_{10},HAuCl_4$ (m. p. 72·5°) and $C_{37}H_{52}NO_{10},AuCl_3$ (m. p. 132—134°) respectively. The methyl iodide compound, $C_{37}H_{52}NO_{10},CH_3I$ (m. p. 121°), has been prepared as a white, amorphous powder by mixing benzene solutions of the alkaloid and methyl iodide.

Although the analytical figures deduced, both for taxine and its salts, are in substantial agreement with the formula, $C_{37}H_{52}NO_{10}$, given by Hilger and Brande (*Ber.*, 1890, 23, 464), the authors are not of opinion that this formula is definitely established.

The alcoholic extract of yew, amounting to about 26 per cent. of the dry leaves, is at present under examination.

Discussion.

Prof. Dunstan remarked that the authors had confirmed the accuracy of previous work on the properties of taxine, and he hoped that they would now be able to go further and throw some light on its chemical structure. It had not been yet fully proved that yew-poisoning was due to the presence of taxine, and indeed even the exact conditions under which yew becomes poisonous did not appear to have been determined with certainty.

Mr. Golding said that in the year 1893 he had assisted Mr. Dymond in an investigation of the alkaloid of the yew. They found that drying the leaves at 100° destroyed the alkaloid.

The extraction of the alkaloid was made from bruised, green, freshly-gathered leaves by Marmé's process, which was repeated several times to purify the alkaloid. Further purification was effected by adding light petroleum to the ether solution, the fractions thus obtained giving the characteristic reactions of taxine.

When dry hydrogen chloride was passed into a solution of the alkaloid in anhydrous ether, and a crystalline precipitate was formed,

which soon changed to a dark brown paste, phenomena also observed by Hilger and Brande.

Cases were on record of animals eating yew with impunity, and a large number of the cases which had proved fatal were due to the eating of *withered* branches.

Dr. VOELCKER pointed out that the uncertainty with regard to poisoning by yew extended to the kind of animal eating it as well as the condition of the leaves. A good deal also depended on the conditions under which it was eaten, whether, for example, much grass or other food was eaten along with it. He thought that it was very desirable that the other substances which the authors had obtained should also be studied, but regarded it as essential that the yew examined should be freshly gathered, and not kept for some considerable time as in the case of that employed by the authors.

Mr. STUBBS, in reply, said that no work had been done to ascertain if the alkaloid contained methyl groups. He did not think that the substance had been produced by the action of the acid used for extraction upon a glucoside. The material employed had been dried in air, at a temperature not exceeding 60°. They had obtained the same amounts of alkaloid from the leaves both when freshly gathered and after they had been dried.

*82. "The sampling of soils." By J. W. Leather.

Experiments were made in India to determine the accuracy of the auger method of sampling soils, and the agreement between the samples was tested by determinations of the total nitrogen, the available phosphoric acid, and the available potash. The results showed that in most cases the agreement was very good between samples, but that in some cases the divergence exceeded 1 in 20, an amount which the author considered too great.

The amounts of phosphoric acid in some of the Rothamsted wheat soils, as found by Dyer, were considered with a view to determine the accuracy of the method of sampling which was there employed. The author considered that such a comparison indicated the Rothamsted method to have yielded as good results as the auger method. Both, however, fall short of what is expected in taking samples of commercial products, and it was urged that the newer methods of soil investigation demand more accurate methods of sampling.

DISCUSSION.

Dr. DYER said that it seemed obvious that a sample drawn from many parts of the field was more likely to be accurately representative

than a sample drawn from one or few places. Nevertheless, it seemed to him that Dr. Leather's analytical results, obtained on samples drawn from different parts of the same field, instead of indicating differences in the samples, appeared really to indicate that both the sampling and the analytical work were excellently performed. Some of the analytical figures regarded by Dr. Leather as discrepant, he (the speaker) should himself regard as being in very good agreement. As to the results of his determinations of phosphoric acid in the Rothamsted wheat soils, which Dr. Leather had quoted, it must be remembered that, whilst the samples analysed represented only the first nine inches of soil, the phosphoric acid removed in the crops might, in the case of wheat, on many plots, be drawn to a considerable extent from the subsoil; and that the influences of vegetation might considerably affect the distribution of soil constituents in the various layers of the soil and subsoil. The "original" phosphoric acid of Broadbalk field, as calculated back from the present contents and known additions and removals, showed, on the whole, as Dr. Leather had pointed out, a fair uniformity, though there were some discrepancies. It was, however, quite probable that the percentage of phosphoric acid in the surface soil was originally by no means uniform on the different plots. Certain of the plots had long behaved somewhat anomalously, indicating some inherent physical or chemical differences in the soil or subsoil.

Dr. Voelcker was inclined to agree with Dr. Dyer, and to regard the results which Dr. Leather had obtained as being very satisfactory. and as agreeing well with one another. It would hardly be a matter for surprise to those who had followed the work at Rothamsted, and who knew the infinite pains which the late Sir Henry Gilbert always took to ensure accuracy in every detail, to learn that Dr. Leather's estimate of gains and loses showed that there could not be much amiss with the Rothamsted method of soil-sampling. Still, it was obvious that the more places in which borings of a soil were taken for sampling purposes the more representative would that sample be.

There was considerable difference between soil samples taken as at Rothamsted (where at least three holes were selected on each plot), and the block of soil ordinarily sent by a farmer when he wished his soil analysed. In the latter case, no doubt, the method Dr. Leather suggested would give a much more representative sample.

The difficulty was in the case of soils of stony character, or where lumps of chalk occurred. The auger might very readily, by pushing these stones or lumps aside, or by including them in the boring, ultimately cause a considerable difference in the analysis.

Mr. Hall said that for some years he had been using an auger for taking samples in the Soil Survey of Kent and Surrey they were carrying out. They used a cylindrical auger one foot long, two inches

Symptoms. — Incontrollable vomiting, with nausea and retching; violent diarrhœa with stools of a serous character, afterwards bloody; violent, griping, abdominal pains; gastric burning; spasms; convulsions; great muscular weakness; paralysis; collapse; but consciousness is preserved to the end.

Post-Mortem Appearances.—Are those of an irritant poison.

Fatal Dose.—℥iij of the *Vinum* has killed.[1] Recovery however has followed half an ounce.

Treatment.—As for irritant poisoning.

Privet (*Ligustrum vulgare*).

This shrub, which grows in our gardens, hedges, and shrubberies is poisonous. Its berries, which in autumn are purplish-black in colour, are sometimes partaken of by children as edible fruit, with development of symptoms of poisoning from which death has happened.[2] Broadbent[3] records a case of poisoning of two children, aged three and five years respectively, who suffered severely after eating freely of the ripe berries, but who both recovered.

Symptoms.—Violent vomiting and purging; weak, thready pulse, subnormal temperature, and coldness of body to the touch; convulsive twitchings or convulsions.

Treatment.—As for irritant poisoning.

Yew (*Taxus baccata*).

This shrub or tree is poisonous, because of the presence of a toxic alkaloid, called by Marmé, taxine. The alkaloid is to be found in every part of the shrub, but mainly in the leaves and berries. Children are liable to be attracted by the beautiful red berries and to eat them. The leaves are popularly believed to be emmenagogic in their action, and for that reason are very occasionally used as an abortifacient; but they have no specific action upon the uterus. The plant is poisonous to animals as well as man. We once made a post-mortem examination of the body of a pet stag, the cause of whose death was likely to be the subject of legal proceedings, as its death was supposed to be due to a mineral poison laid down for the purpose, but we found that the cause was the eating of the leaves of a yew-tree which grew on the lawn of the party supposed to have poisoned it. A horse, too, died from the same cause. In the *Times*, Nov. 1899, an interesting correspondence on the lethal effects of yew upon animals took place. One person wrote that a herd of cows strayed during the night into a field where there was a large yew-tree. In the morning five of the cows lay dead.[4]

Carter states a case where a young woman, suspected to have taken a decoction of yew leaves to procure abortion, was found dead in bed. Death followed in nine hours after taking the decoction, and on post-mortem examination parts of the leaves were found in the stomach.[5]

The seeds are poisonous, but the pulp, if at all poisonous, is much less so, as we have personally eaten of the pulp of several berries more than once without any apparent effect.

Symptoms. — Vomiting; gastro-intestinal pain; weak, irregular action of heart; muscular weakness; collapse; delirium.

Treatment.—As for irritant poisoning.

Post-Mortem Appearances.—Carefully examine stomach contents for portions of leaves; and the stomach and intestines for signs of irritant poisoning.

Conium Maculatum or Spotted Hemlock.

This is a very common plant in our hedgerows, waste heaps, and wild places generally. If the leaves are bruised between the fingers a mouse-like odour is produced from the alkaloid conia or coniin. The leaves are deep green in colour, tripinnate, not unlike parsley leaves; the stem is tall, round, smooth, green in colour, spotted; the root tapering, not unlike a parsnip. The alkaloid, which is

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[1] Wood, *U. S. Dispens.*, 13th Edit., p. 1504.
[2] Taylor, *op. cit.* p. 844.
[3] *B. M. J.*, vol. i. 1884, p. 267.
[4] *Vide* idem, vol. ii. 1899, p. 1377.
[5] Idem, vol. i. 1884, p. 818.

most abundant in the fruit, is fluid at ordinary temperature, has an acrid, bitter taste, and possesses an exceedingly pungent, mousey, or urinous odour. A Pharmacopœial tincture and succus are made from the plant. The plant, or preparations from it, has given rise to accidental, suicidal, and homicidal poisonings. Falck[1] records seventeen cases of death from it, two of them homicidal, one suicidal, twelve accidental, and two from popular medicinal use. On August 4, 1901, a number of boys from an Industrial School were camping out on the Island of Cumbrae in the Firth of Clyde. During their afternoon walk, they chanced to rest where there was a quantity of hemlock growing. Mistaking this for an edible herb, a number of them partook of varying proportions of it. Almost immediately twenty-four of them were seized with violent pains. Emetics were freely administered shortly thereafter, and with the exception of a boy of nine they all recovered. The deceased was very ill from the very outset and never regained consciousness. In March, 1884, several boys belonging to the training-ship *Cumberland* on the Clyde partook of the roots of hemlock. Ten of them became seriously ill, the prominent symptoms being deep stupor and loss of power of limbs. They however all recovered, although in five of the cases the unconsciousness lasted for some hours.[2] Other cases have been reported. Two children, aged four and six years respectively, died from eating the leaves and seeds, death occurring in a few hours.[3] A boy died at Annan, and another at the Island of Sanda from eating the root, which each had picked up in his rambles.[4]

From examination of the plant in the Millport case, it appears that the plant, the root of which was eaten, was *Cicuta virosa*. The symptoms appeared within half-an-hour, the most prominent being headache, giddiness, burning pain in stomach, and sickness. In the fatal case, convulsions came on followed by unconsciousness, and they continued almost without intermission for five and a half hours until death supervened. The spasms or convulsions were very severe, the whole body being perfectly rigid and the spine arched. The boys believed the root to be parsnip.

Symptoms.—The symptoms at first are those of an ordinary irritant poison, but later they exhibit themselves in the form of muscular weakness and gradually deepening paralysis, during which the breathing becomes difficult and slower, delirium, coma, or convulsions supervene, and the patient dies of asphyxia.

Post-Mortem Appearances.—Are those of asphyxia. Look for remains of leaves or root in stomach.

Treatment.—Use of siphon-tube and free lavage of stomach with water containing tannic acid; artificial respiration sustained for a length of time; stimulants, hypodermically or *per rectum;* sustain bodily heat.

Fatal Dose.—Not known.

Chemical Analysis.—Separation of the alkaloid by Dragendorff's process.

Œnanthe Crocata, Water-Hemlock, or Five-Finger Root.

Nat. Ord. = Umbelliferæ.—This is one of our most actively poisonous plants, and is usually found growing near water to the height of from 4 to 5 feet. Its stem is round and smooth, its fruit oblong and black, its leaves when bruised impart a yellow stain to the fingers, and its root resembles a bunch of small parsnips, consisting of from 2 to 10 tubers with rootlets. It has been eaten in mistake for an edible vegetable. One of the most recent cases of poisoning from it is recorded by Griffin.[5] Two men had eaten of what they thought was a piece of carrot; one died, the other recovered. The symptoms came on within 2 hours after eating it.

Symptoms.—In this fatal case, the man fell down in a fit, but soon after regained consciousness. Another fit came on, with vomiting; his face was livid, his pupils dilated and fixed; there was a bloody foam about mouth and nostrils; the breathing was stertorous; and there was complete insensibility. He had six fits or convulsions in all before he died. Death was due to asphyxia. In the case that recovered vomiting was the first symptom; there was no insensibility, but he was delirious, was drowsy, and talked incessantly to himself; his face was

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[1] *Prakt. Toxicologie*, p. 273.
[2] *B. M. J.*, vol. i. 1884, p. 576.
[3] Idem, vol. i. 1881, p. 896.
[4] Idem, vol. i. 1881, Ap. 30, and p. 822.
[5] Idem, vol. i. 1900, p. 509.

pale, his pupils dilated, and the pulse weak and slower than normal. On recovering, he stated that the man who had died had given him the piece of carrot, of which, however, he only took two bites, and then threw away the remainder. This piece was found. It had a strong disagreeable smell, and an acrid taste. The bitten surface was dotted over with reddish-brown, pin-head spots—an appearance which the cut root assumes after exposure for some time to the air. Other cases are recorded, but not of recent years.

Post-Mortem Appearances.—These are indicative of gastric irritation, and of asphyxia.

Treatment.—Use of siphon-tube with free lavage of stomach; artificial respiration; stimulants.

Veratria, Sabadilla cevadilla or officinalis.

(*Veratrum album* = White Hellebore; *Veratrum viride* = Green Hellebore.) Nat. ord. = Melanthaceæ.—Veratria is usually met with as a white amorphous powder, although in Merck's preparation it is composed of rhombic prismatic crystals. Some of the preparations of this plant are officinal. The plants contain several alkaloids.[1]

Symptoms.—Are those of a narcotico-irritant poison, viz.: pain and burning in throat, gullet, and stomach; vomiting; diarrhœa; signs of collapse; coma. Esche[2] experimented upon himself with the drug, and after taking ½ grain of the acetate, his symptoms were as follow: pale, cold, clammy skin, pinched features, rapid, thready, irregular pulse, violent vomiting, marked muscular tremblings, and convulsive movements of limbs. Cases exhibiting toxic effects may be studied under the following references.[3] In the first of these, a woman became insensible after taking the sixteenth of a grain; in the second, an adult man took 30 grains of crude veratria made from *Veratrum viride;* in the third, a person swallowed a quantity of liniment supposed to contain 3 grains of the alkaloid. All these cases recovered.

Treatment.—Use of siphon-tube; maintenance of bodily heat; administration of stimulants; artificial respiration, if necessary.

Fatal Dose.—Death has followed the taking of 18 grains of powdered root of *V. viride.*

Chemical Analysis.—Separation of the alkaloids by Dragendorff's process. The alkaloid—veratria or veratrin—is taken up by benzene or chloroform in alkaline aqueous solution.

Nicotiana Tabacum.

Tobacco is not now used as a therapeutic agent as it once was, but its popular use is perhaps greater than ever it has been. The plant contains a very poisonous alkaloid—nicotin—to which its toxic effects even by smoking must be attributed. The alkaloid is a colourless, transparent, volatile liquid, but develops on exposure to air an amber tint, and latterly becomes a resinous substance. It has a pungent, acrid taste, and produces a greasy-looking green stain on white filtering-paper—conia causing a *pink* stain. The question whether the alkaloid exists in tobacco smoke has been much debated. Some observers[4] affirm that it is absent, and that the derivatives which take its place are mainly pyridin, collidin, and others; others, as Binz,[5] that in addition to pyridin, nicotin is also present as well as CO gas. Cases of acute poisoning are now comparatively rare, but sub-acute and chronic cases are common by reason of the immoderate use of tobacco among boys. An unusual case is recorded by Gill. A convict admitted to Liverpool prison was examined on entrance by the medical officer in the usual way, by whom he was certified to be in fairly good health. Four hours later the convict was found in a state of collapse, with nausea, vomiting, and paralysis of both legs. It seems that he had secreted an

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1 *Vide* Wright and Luff, *Jour. Chem. Soc.*, July 1879.
2 Wood, *op. cit.* p. 159.
3 Taylor, "Med. Jurisp.," vol. i. p. 332; Percy, "Prize Essay," 1864, p. 76; *St. Geo. Hosp. Rep.*, 1870, vol. v.; *Med. Gaz.*, vol. i. 1863, p. 5.
4 Vohl and Eulenberg, *Arch. f. Pharm.* 2, cxlvi. p. 130.
5 Dent, *Aertze-Zeitung*, Jan. 1, 1900.

ounce of cut Cavendish tobacco in his rectum, in order to convey it past the searchers, that on being put into his cell he tried but failed to remove it, with the above consequences. The tobacco was found by the officials in its unusual position. The man recovered.[1] To a child, aged 18 months, suffering from oxyurides, was given an injection consisting of a decoction of two cigars. The child thereafter began to vomit and to be convulsed; it then lapsed into a state of coma, with frequent, feeble pulse, cold extremities, irregular respiration, and contracted pupils. It recovered. Both cigars contained about 2½ drachms of tobacco.[2] O'Neill records an interesting case where toxic effects followed the external application of the leaf. A woman suffering from varicose veins accidentally wounded herself; to staunch the blood a handful of chopped tobacco was applied to the wounded surface and kept in position by a bandage. The patient became extremely prostrated, almost pulseless, her skin was pale and cold, her pupils dilated, and she suffered from much pain in abdomen, with nausea and vomiting. She got better after a lapse of several days.[3]

Symptoms.—When the leaves are swallowed—as in a quid—or where immoderate smoking has been indulged in by one unaccustomed to smoke, the principal symptoms found are: giddiness, depression, sickness, vomiting, muscular tremors, feeble, rapid, and, it may be, irregular pulse. Morrow[4] has drawn attention to a peculiarity in the breathing of persons suffering from nicotin poisoning by smoking, viz.: a form of Cheyne-Stokes' respiration in which there is a deep inspiration, followed by absence of rhythmic respiration for a considerable interval, then succeeded by another deep inspiration. He adduces three cases in which this phenomenon was seen. He made a series of experiments on rabbits to discover its physiological basis, and by tracings shows that the poison of tobacco seems to act chiefly on the respiratory centre, paralysing the expiratory division of it. The symptoms after taking the alkaloid are more acute than those described. These are a burning, acrid taste in mouth and throat, followed by nausea, vomiting, rapid unconsciousness, symptoms of shock, gasping or sighing and irregular respiration, with delirium, and, possibly, convulsions. In the early stage of acute, and in all stages of sub-acute poisoning, the pupil is contracted, but in the later stage of acute poisoning it becomes dilated.

There is reason to believe that in the form of snuff or powdered tobacco, it is sometimes feloniously put in liquor for the purpose of enabling the easier commission of such crimes as theft. The only homicidal case on record is that recorded by Tardieu,[5] in which Count Bocarmé and his wife were convicted of murdering their victim—Fougnies—by administering forcibly the alkaloid which Bocarmé himself had made.

Chronic Poisoning.—There can be little doubt that the use of tobacco in the form of cigarettes by boys of immature age is productive of considerable constitutional mischief, especially if the smoke is inhaled. This is indeed true of all who inhale the smoke. Not to speak of the dyspepsia, anæmia, and stunted growth which are produced, it gives rise to nervous troubles and to tumultuous, and sometimes irregular action of the heart; indeed, "tobacco heart" is a well-known condition in present-day medical practice.

Post-Mortem Appearances.—These are very indefinite. Death would seem to be due to asphyxia, and therefore the post-mortem signs of that form of death are likely to be found. In all cases, the contents of the stomach should be examined for remanent parts of the leaf, leaf-stem, or mid-rib. In odd cases where the leaf has been swallowed, the odour of tobacco may be perceived in the stomach; in other cases, the odour cannot be counted upon.

Fatal Dose.—An enema of half a drachm, and one of a drachm of the leaves have caused death, but recovery has followed the use of an enema in which half an ounce of snuff and five leaves were mixed. Of the alkaloid probably 10 to 20 milligrams would cause death.

Fatal Period.—In fifteen minutes, after enema.[6] In three to five minutes from nicotin.[7]

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1 *B. M. J.*, vol. ii, 1901.
2 *The Lancet*, vol. i. 1879, p. 206.
3 Idem, p. 296.
4 *B. M. J.*, vol. i. p. 1406.
5 Vide *L'Étude Méd.-Leg. sur. l'Empoisonnement.*
6 Beck, "Med. Jurisp.," vol. ii. p. 878.
7 Taylor, *op. cit.* vol. i. p. 393.

Chemical Analysis.—Examine contents of stomach for fragments of leaves, which may be recognised microscopically by the small glandular hairs which they possess. The contents may then be treated by the Stas-Otto or Dragendorff process for the alkaloid, which consists of oily-looking drops.

Lobelia.

(*Lobelia Inflata*, or Indian Tobacco.)—This plant possesses toxic properties by reason of the active principle Lobeliin or Lobelin which it contains. This has an action somewhat akin to tobacco. It is a favourite remedy of the "Thomsonian" or "Coffinite" school of practitioners, who assert that it is not a poison. It is commonly used in America as a drug, and has very often given rise to fatal effects. In 1884, a herbalist in England was charged with having caused the death of a woman by administering lobelia in an acetic acid solution. The woman only survived its administration some forty minutes, previous to which she had been profusely purged. It was shown in evidence that the woman had taken of the solution prescribed an equivalent of 28 grains of the drug. At the trial[1] several witnesses were called for the defence—all of them herbalists—by whom it was asserted that the drug was not a poison, that the Committee of the House of Lords in 1857 struck it out of the proposed list of poisons; and one of the witnesses testified that he himself had taken 960 minims of lobelia without being poisoned. The jury, owing to the summing-up of Mr. Justice Watkin Williams, returned a verdict of not guilty.

Symptoms.—The main symptoms are those of a depressant nature; vomiting is usually an early symptom; the pulse becomes weak; the pupils dilated; the patient becomes insensible and collapsed prior to death.

Treatment.—Evacuation of contents of stomach by tube and free lavage with water; stimulation hypodermically by ether, or *per rectum* by alcohol; restoration and maintenance of bodily heat.

Fatal Dose and *Fatal Period* are both uncertain.

Chemical Analysis.—In Dragendorff's process lobelin is extracted from an alkaline aqueous solution by petroleum ether, and gives with Fröhde's reagent (1 part of sodic molybdate dissolved in 10 parts of strong sulphuric acid) a deep violet solution which gradually fades.

Alcohol (C_2H_6O).

Having already considered the toxic appearances from alcohol (p. 346), it is only necessary to describe now the salient characteristics of alcoholic intoxication, and their modifications by the use of different forms of alcohol. The chief signs of alcoholic poisoning are these: deep unconsciousness; face pale, with occasionally some degree of cyanosis of lips; subnormal bodily temperature; regular, deep, but not stertorous breathing; pupils are contracted if the person is allowed to remain undisturbed for fifteen minutes, but become dilated on the application of any stimulation. We consider such pupillary conditions to be pathognomonic of the alcoholic state.

In poisoning by methyl-alcohol, we are of opinion that the unconsciousness is more profound, and that the person recovers less rapidly.

Amylic Alcohol.—Cases of poisoning from amylic alcohol ($C_5H_{12}O$) are comparatively rare. The case recorded by Ord is full of interest.[2] A coal-porter drank about half a pint of fousel oil at 5.30 A.M., went to his work, and at 10 A.M. became unconscious. When brought to St. Thomas's Hospital at 12.30 P.M. he was still unconscious, the muscles of his arms and legs were rigidly extended, as were also those of the neck and back; his teeth were tightly clenched; his face bluish; the

[1] *B. M. J.*, vol. i. 1884, p. 343.
[2] *The Lancet*, vol. ii. 1889, p. 1225.

breathing shallow and infrequent; pulse could just be detected at wrist; pupils small, but they acted feebly to light; conjunctival reflex was absent; body-surface was cold. His breath had the odour of amyl-nitrite or jargonelle pear, and the washings from his stomach the same, but even more marked odour. He recovered consciousness next day, and left the hospital two days later. Dr. Bernays examined the remaining portion of the liquid which he had taken, and found that it was composed of half fousel oil and half spirit; the urine, which he also examined, contained traces of amylic alcohol. It will be noticed that the pupillary condition on his admission was one of contraction, and that during artificial respiration the pupils became dilated. Ord further states that the fumes of the spirit which were exhaled from the patient produced in those who attended him severe frontal headache, giddiness, and feelings of malaise which lasted for some hours. Swain[1] also records a fatal case from this impure alcohol.

The continuous use of the liqueur—absinthe—produces disastrous effects upon the nervous system of habitués; but this is owing to the contained santonin or wormwood.

Treatment.—Restoration of bodily heat, by wrapping person in blankets and placing him in the recumbent position before a fire; use of siphon-tube and free lavage of stomach.

Post-Mortem Appearances.—The post-mortem signs generally are those of asphyxia. In the stomach, the characteristic odour of ethyl-, methyl-, or amyl-alcohol—depending upon which form of alcohol predominates in the liquor taken—is likely to be found.

In poisoning by amyl-alcohol the mucous membrane of the stomach is likely to be more or less injected and softened. In the case narrated by Swain, the stomach contained some grumous fluid tinged with blood.

Chemical Analysis.—Alcohol may be separated from vomited matter or stomach contents by careful distillation, after they have been made neutral with sodium carbonate. Amylic alcohol may be separated by shaking up the mixture with chloroform after filtration, separating the chloroform layer, and allowing it to evaporate, when the characteristic odour will be perceptible. If necessary, this residue may be distilled with potassium acetate and sulphuric acid, when amyl-acetate—recognised by its peculiar odour—will distil over.

Camphor.

The resin of camphor, because of its popular use as a personal disinfectant and as a preservative of clothing against moths, has given rise to toxic results in children who have inadvertently eaten of it. The Pharmacopœial preparations—liniments and spirit especially—have been drunk by mistake, sometimes with fatal results.

Symptoms.—Vomiting, unconsciousness, foaming at mouth, pallor of face with lividity of lips, and, in children especially, convulsions. In one case which we saw, in addition to the foregoing symptoms, the pupils were dilated.

Treatment.—Evacuation of contents of stomach by siphon-tube and free lavage with water; maintenance of bodily warmth; stimulants *per rectum;* artificial respiration.

Post-Mortem Appearances.—The characteristic odour of camphor will be

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[1] *B. M. J.*, 1891.

found, and there is likely to be some inflammation or injection of mucous membrane of stomach.

Chemical Analysis.—Shake up contents of stomach or vomit with chloroform; separate chloroform; allow to evaporate spontaneously.

Fatal Dose.—Twenty grains has killed an adult; adults have recovered, however, from doses eight times that quantity, and a child has recovered from the effects of swallowing a teacupful of camphorated oil, containing between 100 and 200 grains of camphor, although it had convulsions and all the signs of collapse.[1]

Turpentine.

Spirits or oil of turpentine being used for a variety of domestic purposes gives rise, occasionally, to accidental poisoning in children and adults. Being volatile, its vapour produces certain physiological effects upon those who are exposed to it for lengthened periods. Cats and rabbits exposed to it die within a short time—less than an hour. Before death they exhibit uneasiness, unsteady gait, paralysis of hind limbs, difficulty in breathing, and convulsive movements. The proximate cause of death is asphyxia. Grapel records a case[2] of a woman who swallowed by mistake about 9 P.M. one to one and a half ounces of turpentine. At 10.40 P.M. she awoke feeling very cold and with a sensation of dying; she was giddy, and on trying to walk, staggered in her gait. Next morning, micturition was accompanied by great pain, and was followed by the passage of clotted blood *per urethram*. For several days she suffered from pain in the loins, headache, loss of appetite, and blood after the act of urinating; during the night she was partly delirious, and she was somewhat feverish. The urine had a pungent odour of "violets," which continued for twenty-four days, but in a less marked degree after the first three or four days. Her menses, which were eight weeks overdue, came on the day after she took the turpentine. In another case,[3] a woman with suicidal propensities took half a pint of turpentine. The siphon-tube was passed soon after, free lavage of the stomach being employed for half-an-hour with cold water, but with the exception of the odour of "violets" in the urine, there was little left by which her act could be traced. The stomach-washings smelled strongly of the turpentine, but there was no odour of it in the breath or upon the clothing.

Symptoms.—Burning in mouth and stomach; vomiting, thirst, giddiness, unconsciousness, strangury, odour of "violets" and blood in urine; coma usually precedes death.

Treatment.—Evacuation of stomach by siphon-tube and free lavage with cold or tepid water, till washings are nearly free from turpentine odour; then warm milk into stomach; purgative dose of castor oil; restoration of bodily heat.

Fatal Dose.—℥ss killed a child; one teaspoonful, an infant. Four ounces and six ounces respectively have killed adults.

Fatal Period.—In the case of the child who took half an ounce, fifteen hours; in the adult, twelve hours.

Benzene (C_6H_6).

This substance which is found as a clear, colourless, volatile liquid with a suffocating, disagreeable odour, akin somewhat to coal-gas, produces toxic effects not only when swallowed, but also when the vapour is inhaled, as in glove-cleaning, in dye-works, and in aniline manufactories. Foulerton[4] narrates the case of a man who, entering a tank where this vapour had accumulated, was found unable to stand, and although partly insensible was able to answer questions. He was excited. His face was flushed, but his body was cold. Pupils were dilated, but mobile. His respirations only numbered 8–9 per minute, and were deep, stertorous, and irregular in rhythm. He recovered. Kelynack[5] records the facts of a case in which a woman drank about an ounce of benzene from which she died twelve hours after.

[1] Wilkinson, *B. M. J.*, vol. i. 1898, p. 299.
[2] *B. M. J.*, vol. i. 1901, p. 340.
[3] Idem, p. 640.
[4] *The Lancet*, vol. ii. 1886, p. 865.
[5] *Med. Chron.*, vol. 19, 1893, p. 112.

Symptoms.—Excitement; partial or complete insensibility; dilatation of pupils; symptoms of shock; embarrassed, slow respiration; gastro-intestinal irritation—vomiting, diarrhœa; collapse.

Post-Mortem Appearances.—Bodily cavities yield odour resembling coal-gas. Signs of death by asphyxia. The stomach conditions are remarkably negative.

Fatal Dose.—One ounce or less.

Fatal Period.—Uncertain.

Chemical Analysis.—Distil the contents of stomach; recognition of odour in distillate.

Naphthalin ($C_{10}H_8$).

This is a poisonous substance, although it has been sometimes described as harmless. Zangerle [1] narrates the case of a boy of twelve who came home one night with symptoms which were much like those of alcoholic intoxication. It appeared, however, that he had eaten two naphthalin camphor tablets which another boy had given to him as "bon-bons." Each tablet contained two grammes of pure naphthalin. Meyer experimented on rabbits and cats with these tablets, and found that they produced muscular inco-ordination of hind limbs and attacks of sneezing and vomiting. The animals died. Evers [2] records the case of persons who suffered from loss of appetite, headache, and eczema of both legs, from having slept under bedclothing which had been dusted over with naphthalin as a moth-powder. Gotze [3] and Fronmüller [4] record other cases of poisoning; the former, where the naphthalin was administered internally in enteric fever, the latter, from absorption from wounds, to which it had been used as an antiseptic application.

Aniline Oil, Anilin ($C_6H_5NH_2$), or Phenylamine.

This is a colourless, oily fluid, which, after standing, may develop a shade of brown colour. It has a peculiar odour. It has very toxic properties, not only when swallowed but when absorbed through the unbroken skin. Several cases from both causes have been recorded. Müller [5] records that of a woman who swallowed about 25 c.c. of anilin, and Smith [6] that of another woman who swallowed about three ounces of marking ink, the greater part of which was anilin.

St. Clair Thomson [7] narrates the case of a man who was prescribed as a menstruum for the aural application of cocaine equal parts of anilin oil and rectified spirit. The cocaine was introduced into the ear on a pledget of cotton-wool at night. The man slept well. He renewed the application at 5 A.M., because of the pain returning. At 7.30 A.M. he accidentally noticed a peculiar blueness of his finger-nails, and his wife remarked that his face also was blue. There was a like colour of lips and tongue. There was no fever nor mental disturbance, the pupils were normal, but the apex beat of the heart was observed to be two fingersbreadth outside the left nipple line. The blue colour disappeared during the day, and the area of cardiac dulness again became normal. A very remarkable case of its effects on newly-born children after absorption is narrated by Rayner.[8] The napkins of the infants in an institution were marked with an official stamp in large letters. The ink used was aniline chloride. The blue coloration, already described, appeared on the lips, gums, and palate of some of the children.

Symptoms.—These appear rapidly, as a rule, after swallowing the poison, and consist of nausea and vomiting, giddiness, drowsiness lapsing into coma, along with a remarkable development of blueness of face and body; the skin is cold and clammy, the bodily temperature is subnormal, the pupils dilated and immobile, and the pulse small, feeble, and irregular. If the blood be examined during life, it yields a spectrum of met-hæmoglobin.

Post-Mortem Appearances.—The signs of death by asphyxia are met with. The blood is very dark in colour.

Fatal Dose.—From 3 to 6 drachms.

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[1] *Therap. Monats.*, Feb. 1899.
[2] *Berl. klin. Woch.*, 1884, p. 593.
[3] Idem, 42, 1884.
[4] *Memorabilien*, 1883, v. 237.
[5] *Deutsche. med. Woch.*, 1887.
[6] *The Lancet*, vol. i. 1894, p. 89.
[7] *B. M. J.*, vol. i. 1901, p. 957.
[8] *Ibid.*, vol. i. 1886, p. 294.

Fatal Period.—Uncertain.

Treatment.—Wash out stomach freely with siphon-tube; administer stimulants hypodermically, or *per rectum;* sustain bodily heat; and use artificial respiration if necessary. In cases resisting benefit from the foregoing, bleed the patient at the arm and transfuse live human blood.

Chemical Analysis.—The poison may be obtained by rendering alkaline the vomited matter or stomach-contents and then distilling; or if the vomited matter be fairly free of organic solids, after filtration, the filtrate is made alkaline and shaken up with ether; the ether is then separated and allowed to evaporate spontaneously. The poison will be found in distillate or residue.

Paraffin Oil.

Paraffin oil, or rock oil, or petroleum, whether obtained as a natural product or from the destructive distillation of oil shale, produces toxic effects when swallowed. Although these are not identical chemically, their effects when swallowed are practically alike. It must be said that compared with most other poisons paraffin oil is relatively less poisonous, the toxicity depending rather upon the quantity taken. It has been taken both accidentally and suicidally, but there is no case on record in which it has been used homicidally. This is doubtless owing to its tell-tale odour. It has caused death in the case of children. Carruthers [1] has recorded a case with unusual symptoms. A woman, aged 36, while under the influence of alcohol, swallowed half a cupful of paraffin oil. Half-an-hour later she was seized with violent abdominal pain and vomiting. Three hours later the pain in stomach still continued, and the vomited matter contained marked indications of the oil. Her breath had a distinct odour of it, and in her motions paraffin oil and blood were present. In the urine after standing, a quantity of oil formed a scum on its surface. The urine yielded 6 c.c. of oil after distillation; later, it contained blood and albumen. She recovered completely in a week.

The practical difference between petroleum and paraffin oil is that the former contains higher hydrocarbons than the latter. This appears to effect some difference in the symptoms produced. Johannsen [2] records a case in which a girl of twelve drank a quantity of American petroleum. Her symptoms were as follows: she became cyanotic, her breathing quickened and laboured, she was drowsy, she vomited, and died comatose in five or six hours. The vomited matter and motions contained the oil.

Post-Mortem Appearances.—The stomach will contain a marked odour of the oil; but there may not be any unusual appearance in the mucous membrane of its wall. The signs, generally, are those of death by asphyxia.

Treatment.—Evacuation of contents of stomach by siphon-tube and free lavage with warm water; administration of stimulants *per rectum;* maintenance of bodily heat; artificial respiration if required; purgatives, to rid intestines of oil.

FORMALIN.

The use of formaldehyde, or formalin, as the 40 per cent. solution in water of the former is called, as a disinfectant for the aerial disinfection of rooms, is bound sooner or later to give rise to cases of poisoning from its accidental or suicidal use. A few cases have already been recorded. Klüber [3] and Zorn [4] have each recorded a most interesting case. The patient in Klüber's case—a man of 47—drank some Apenta water in which formalin had been put by mistake; in the other case by Zorn, a man of 44 took about 15 c.c. of formalin by mistake. In the former case, the patient was completely insensible, could not be roused in any way, the face was pale, the body covered with sweat, the pulse was 78, and the temperature 99° F. Twelve hours after swallowing the poison

[1] *The Lancet*, vol. ii. 1890, p. 442. [2] *Med. Chron.*, 1898.
[3] *Münch. med. Woch.*, Oct. 9, 1900.
[4] Idem, Nov. 13, 1900; *B. M. J.*, 1901, vol. i. sup. p. 9.

the man became conscious although still stupid, but again lapsed into a state of somnolency, from which he could now be roused. He had passed no urine for 19 hours. That night he became excited, laughed loudly, but was quite sensible; his eyelids became red, and there was profuse running at the eyes; the mucous membrane of the mouth and soft palate was red and inflamed. After a night's good sleep, he was well enough to return to work.

In Zorn's case, the patient had violent retching and vomiting shortly after swallowing the poison, accompanied by dyspnœa, vertigo, and a burning pain in mouth and stomach, his skin became cold, the bodily temperature sub-normal, the lips and extremities somewhat cyanosed, the pulse 126, and the respirations 44. He never lost consciousness, but on trying to stand, fell and hurt his forehead. There was complete anuria for 24 hours The stools which he passed during the first day and night thereafter were six in number, were dark in colour, syrupy in consistence, and were accompanied by violent tenesmus. They contained Charcot-Leyden's crystals, much mucus, but no blood.

In the urine of each of these persons, formic acid was shown by the blackening of ammonio-nitrate of silver, and by the characteristic reaction with anilin.

Treatment.—Use of siphon-tube and free lavage with tepid warm water. Ammonia internally, in the form of the diluted liquor or Liq. ammon. acetatis has been recommended as an antidote,[1] because it combines with formaldehyde to form hexamethylemetetramin (urotropin) which is not poisonous, according to the formula: $6(HCOH) + 4NH_3 = (CH_2)_6N_4 + 6H_2O$.

ABORTIFACIENT AND APHRODISIAC DRUGS.

Ergot.

Ergot is found in medicine as the powder, liquid extract, and ergotin, the last containing the active principles of the drug, viz.: ergotinic acid, sphacelinic acid, and cornutin. Its action is ecbolic and emmenagogic; it is, therefore, sometimes used as an abortifacient by quacks for illegal purposes. Ergotised rye, being occasionally used inadvertently for making bread, has given rise to chronic poisoning, and is toxic to animals as well as to man.

Few fatal cases from acute poisoning have been recorded, and then only when large quantities of the drug have been taken. In criminal abortion death may however happen from uterine hæmorrhage following its use. Davidson[2] records a case where a pregnant woman took "two handfuls" of powdered ergot. The next day her face and upper half of body were jaundiced, and ecchymoses were found under the eyes; the lips and tongue were swollen and covered with dried, dark-coloured blood; she vomited reddish mucus and blood; she had great thirst; her temperature was sub-normal; the pulse could just be felt, but could not be counted; and the cardiac

[1] *Therap. Monats.*, Feb. 1901; *B. M. J.*, vol. i. 1901, sup. p. 7.
[2] *The Lancet*, 1882.

$(CH_2)_6N_4 + 6H_2O$

beats numbered 150 per minute; respirations were 48 per minute. She looked drowsy, apathetic, and stupid. The urine contained blood. She died.

Symptoms of Acute Poisoning.—These include: pain in stomach, nausea, vomiting with or without blood, thirst, weak, rapid pulse, feeling of oppression in chest, sub-normal temperature, coldness of body, cramps, convulsive movements, stupor, delirium, convulsions, and coma.

Of Chronic Poisoning.—These are indicative of gastro-intestinal catarrh, of nervous exhaustion or excitement sometimes amounting to mania, and dry gangrene of parts at the extreme periphery of the circulation—fingers, toes, etc.—due to contraction of arterioles, and therefore to imperfect blood-supply.

Post-Mortem Appearances.—Jaundice may be found in the skin and mucous surfaces. The internal signs are sub-mucous extravasations of blood in stomach, extravasations in liver and kidneys, and in abdominal cavity. Careful examination of contents of stomach should be made for remains of the powder.

Treatment.—Use of siphon-tube with free lavage of stomach with warm water; stimulants, hypodermically or *per rectum;* inhalations of nitrite of amyl; restoration of bodily heat.

Chemical Analysis.—The vomited matter, or contents of stomach, is mixed with boiling alcohol and filtered. The process being repeated several times, the filtrates are united and acidulated with dilute sulphuric acid. The bulk of alcohol being evaporated off, a portion of the residual liquid is examined spectroscopically; if ergot be present, a spectrum is found composed of two bands, one in the green, and a second, broader and more marked, in the blue. A parallel test should be made with a solution of ergot identical in colour-tone to that of the residue. If another portion be rendered distinctly alkaline with caustic potash and heated, the characteristic odour of trimethylamine—that of herring-brine—is given off.

Savin.

(*Savina communis, Juniperus sabina.*)—This is an evergreen shrub common in gardens. The leaves and fruit contain a volatile oil having toxic irritant properties. It has held for centuries the reputation of producing abortion; indeed, its action for this purpose is mentioned in the old Scots ballad of Marie Hamilton. It is a debatable point whether savin has a specific ecbolic action, or whether, if this action is exhibited, it is not simply a part of a general toxic effect upon the body. Blyth[1] narrates a case in which he was engaged in which a pregnant woman took an infusion of savin tops, from the effects of which she died in twenty-six hours. Her symptoms were violent sickness, great pain, and diarrhœa. On post-mortem examination of the stomach and its contents, he was able not only to detect some of the savin tops, but also to separate a few drops of an odorous oil, like savin, by distillation. In several cases, strangury with bloody urine has been observed.

[1] "On Poisons," p. 442.

Post-Mortem Appearances.—These are mainly redness of pharynx and gullet and inflammation of stomach, in addition to irritation of kidneys. The remains of the plant ought to be sought for in the vomited matter and contents of stomach.

Pennyroyal.

(*Hedeoma pulegioides.*)—This is perhaps the most popular emmenagogue. Like savin, the plant contains a volatile oil which has toxic properties. Of laté years, several cases of its toxic effects have been recorded. Wingate[1] records one in which a pregnant woman of twenty took a teaspoonful of the oil. She became unconscious with delirium, and was attacked by tetanic spasms producing opisthotonos, and exhibited all the signs of shock. She recovered, but did not abort.

Allen[2] narrates another of a woman who after taking a tablespoonful of the oil vomited persistently for four days, and died on the eighth day.

Post-Mortem Appearances.—Congestion of stomach and small intestines, due to irritant action of poison.

Tansy.

(*Tanacetum vulgare.*)—This plant, which grows wild and is common in old-fashioned gardens, possesses a strong, pungent, but not disagreeable odour. It, also, has a popular reputation as an ecbolic. The plant contains a volatile oil with poisonous properties. Jewett[3] records a case of a woman of twenty-nine who took fifteen drops of the oil, and three hours later a teaspoonful. In a quarter of an hour after the larger dose she gave a shriek, became convulsed, during which respiration was suspended, and her face became cyanosed; the pupils were widely dilated. She also exhibited signs of shock. The odour of the oil was perceptible both in her breath and in the vomited matter, vomiting having been induced by an emetic. She recovered. Fatal results, however, have been produced; in one case, after about eleven drachms of the oil had been swallowed.

Post-Mortem Appearances.—These are practically negative. The tell-tale odour of the oil, however, is usually present in the stomach, upon which the diagnosis of cause of death must mainly be founded.

Treatment.—This is, on general lines, identical to that for any other irritant poison.

Cantharides.

(*Cantharis vesicatoria.*)—The active principle of Spanish flies is *cantharidin*, which is insoluble in water, but freely soluble in hot alcohol, ether, chloroform, and fixed oils. When taken into the body it is chiefly eliminated by the kidneys and intestines. Popularly it is believed to have marked aphrodisiac action on both

[1] *Boston Med. and Surg. Jour.*, 1889.
[2] *The Lancet*, 1897, vol. i. p. 1022.
[3] *Boston Med. and Surg. Jour.*, 1880.

sexes, and it is also believed to have abortifacient action. It has been used criminally for both purposes. The official medicinal preparations of it are: *acetum cantharides*, the *tincture*, and *liquor epispasticus*. Besides these, there are several proprietary blistering preparations.

It is usually administered for abortifacient purposes in the form of the powder, but other preparations have been given. It has been given homicidally in the form of blistering-paper mixture in soup.[1] A boy of twelve suffering from meningitis, and upon whose head behind the ear a cantharides blister measuring four inches square had been applied, took it off, chewed it, and died with the symptoms of poisoning.[2]

Symptoms.—A burning pain in throat and stomach; subsequent difficulty in swallowing; nausea and vomiting, the vomited matter

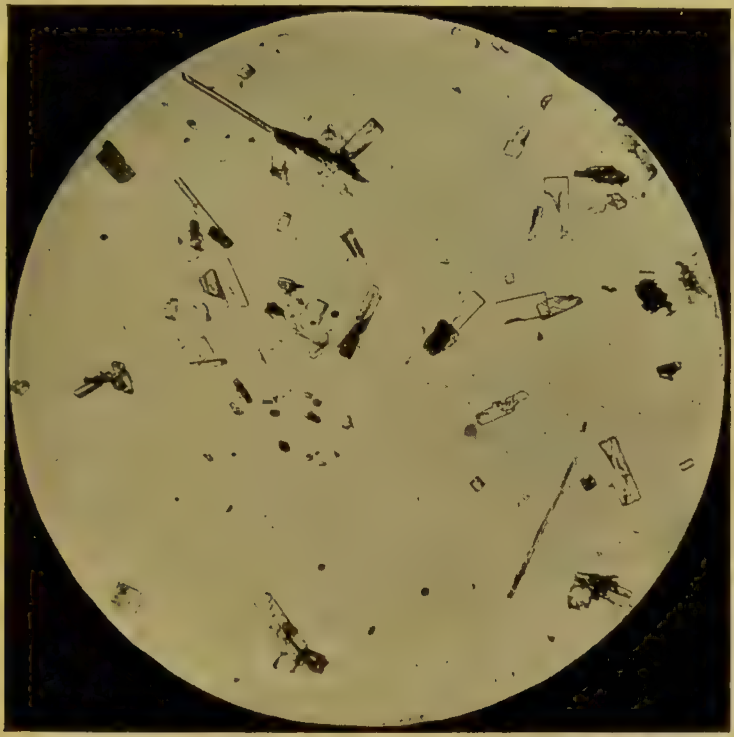

FIG. 107.—Photo-micrograph of crystals of Cantharidin obtained from the *Cantharis vesicatoria*, or Spanish fly. × 500 diameters. (Author.)

containing blood; intense thirst; there may be diarrhœa. Strangury, with great tenesmus and the passage of bloody urine, is a prominent symptom. In fatal cases, coma with convulsions usually precedes death.

Post-Mortem Appearances.—Gastro-intestinal inflammation, due to the vesicating action of the cantharidin. This is chiefly marked on mucous membrane of stomach and upper intestines. The kidneys exhibit marked signs of congestion and inflammation, macroscopically

[1] *Jour. de Chimie*, 1846, p. 606.
[2] Muir, *B. M. J.*, vol. i. 1881, p. 1012.

and microscopically, and bloody urine may be found in bladder. In view of the fact that the powder is commonly given, the stomach and intestinal tract should be carefully searched for remains of the shining *elytra* or wing-cases of the insect.

Treatment.—Evacuation of stomach-contents with siphon-tube and free lavage with tepid water, followed by demulcent fluids. After vomiting has ceased, excretion of urine should be aided by the use of warm demulcent drinks, as barley water, and the bowels should be cleared by a saline purgative, but *not by castor oil.*

Chemical Analysis.—If portions of the wing-cases have been found they should be set apart for special examination. The vomited matter or contents of stomach should be acidulated with sulphuric acid, and thereafter shaken up with chloroform, the chloroform layer separated and filtered, if necessary; the bulk of the fluid is then allowed to evaporate spontaneously, and a drop of the residue, mixed with a drop of olive oil, is taken up on a tiny piece of cotton-wool and applied to the skin on the inside of the arm near the elbow, when, if cantharides be present, its blistering action will become apparent. For the estimation quantitatively of cantharidin, Dragendorff's system must be used.

Fatal Dose.—Twenty-five grains of the powder killed a young woman; and one ounce of the tincture (Taylor) has produced a like effect. Recovery, however, has followed larger doses.

Fatal Period.—Uncertain.

Santonin.

(*Artemisia maritima.*) Nat. Ord. = Compositæ. Wormwood has had for a long time a popular reputation as an aphrodisiac and has been used for this purpose. From the plant is obtained the active principle—Santonin—which is a crystalline substance, composed of brilliant, four-sided, flat prisms, white or faintly yellow in colour, hardly soluble in cold water, but freely soluble in alkaline water. It is commonly used as a vermicide in children. Robinson has recorded a case where an infusion of the plant was used for the first-named purpose. A gentleman took a quarter of a pint of the infusion at 8.30 A.M., after breakfast, and in an hour afterwards he was seized with vertigo, weakness and tremblings in his limbs, a dragging pain in the lower part of abdomen, constant desire to micturate, and a burning sensation at the point of the penis. These symptoms lasted for about forty minutes, and then gradually passed away.[1] It has been not infrequently given in overdose to children,[2] and it has been taken by mistake for Epsom salts.

Symptoms.—In addition to giddiness, nausea and vomiting, pain in the stomach, saffron-yellow coloured urine, with perhaps hæmoglobinuria, disturbance of vision takes place Yellow vision or xanthopsia comes on, lasting for many hours, sometimes preceded by violet vision, which however is of shorter duration. In fatal cases, coma and convulsions precede death. Chronic poisoning from santonin is observed in absinthe-drinkers, the main effects produced being total derangement of the nervous system and moral insanity.

1 *The Lancet*, vol. i. 1889, p. 770. 2 Idem, 1879, p. 206.

Post-Mortem Appearances.—Nothing characteristic is found either in the stomach or in the body generally.

Fatal Dose.—·12 gramme (about two grains) of santonin killed a boy of five and a half years in fifteen hours. But a man who took one ounce in mistake for Epsom salts recovered.[1]

Treatment.—Prompt evacuation of contents of stomach by tube or emetics. Injections of chloral *per rectum.*

Chemical Analysis.—By the Otto-Stas or the Dragendorff process santonin is obtained from the chloroform solvent when used in acid solutions. Its identity is established by dissolving it in strong H_2SO_4 and a little water, warming the mixture, and then adding a few drops of ferric chloride, when a beautiful red passing into purple colour forms round the iron solution. In the urine, its presence may be proved by first adding a little caustic potash solution, when a red colour forms, next precipitating the reddened urine by baryta water, and filtering. If the red colour remains, it is due to santonin; urine itself losing by filtration the red colour originally formed.

FOOD POISONING.

It has already been more than once noted that toxic symptoms may follow the ingestion of certain foods prepared by the process of "canning," but in the bulk of cases these have been traced to the presence of mineral poisons in the food due chiefly to their solution by the acid juices of the contained food. The metallic poisons thus dissolved are mainly lead and tin; and there can be no doubt that toxic symptoms follow in such cases. But from time to time cases arise singly and collectively in which poisonous effects are produced which cannot be traced, after chemical examination, to the presence of any mineral poison in the food. Independently, therefore, of such mineral poisons and of parasitic conditions, food-poisoning may arise from alkaloidal principles in food which are produced by the action of micro-organisms on the organic substances, and which are of the nature of albumoses, tox-albumins, or ptomaines Such toxic effects may follow the use of flesh meat, milk or cheese, bread, and other substances.

Meat.—It is but rare that mischievous effects follow the ingestion of healthy, properly-cooked flesh meat. Should, however, an animal have been slaughtered after it has been drenched with drugs which are poisonous to man, evil effects may result; but this is not the kind of case we are considering, although it must not be overlooked. It is when meat has been prepared in special ways that these toxic symptoms succeed; as for example, in the form of sausages, corned beef, brawn, potted meats, "canned" goods, and pies. Botulism—which is the name given to a certain series of toxic symptoms arising from the presence of *B. botulinus* in sausages—is by no means unknown in France, Germany, and other Continental countries, where, as well as at home occasionally, the sausages are eaten raw or imperfectly cooked. Ballard[2] has reported upon a fatal case of a gardener who died eight days after eating sausage, called

[1] *Annal. univ. de Med.*, 1882.
[2] Supp. Eleventh Rep. Loc. Gov. Bd., 1881.

"German sausage," after having suffered from vomiting, purging, etc., and latterly, from lung implication, with rusty, viscid sputum. Klein subjected mice to experiment with this sausage and found like toxic symptoms produced. In Germany, especially, series of cases have been reported from eating sausages, in which the most marked toxic effects were extreme dryness of skin and mucous membranes, dilatation of pupils, and paralysis of the upper eyelid muscles. Accompanying these symptoms were: nausea, vomiting, diarrhœa, which is never choleraic, however; dryness of mouth and nose and pharynx, constipation, in addition to disturbance of vision, amounting at times to diplopia. On post-mortem examination of the bodies of those who have died, the main appearances found are: white, dried, parchment-like condition of mucous membranes of mouth, throat, and gullet; the lining of stomach is injected and marked with extravasations of blood; the spleen is enlarged and congested, the kidneys congested and containing blood in the tubules, and the lungs are œdematous, with evidence of pneumonia or bronchitis. Ossipoff[1] has investigated the effects of the anaerobic organism—*B. botulinus*—discovered by v. Ermengem in 1895, which he isolated from cultures made from preserved ham. Ossipoff experimented on guinea-pigs, and found that they suffered from the following symptoms, viz.: (*a*) suppuration of eyelids; (*b*) retention of urine and constipation; (*c*) dilatation of pupils; (*d*) paresis of limbs; (*e*) dyspnœa; (*f*) progressive asthenia, ending in death. Marked changes were found in the intimate structure of the grey matter of the spinal cord, and less marked changes in the medulla, cerebellum, and cortex of the cerebrum.

Cold boiled ham has been the cause of several attacks of poisoning. Among the earliest recorded was the Welbeck case,[2] the facts of which were minutely investigated by Ballard. Seventy-two persons were attacked and suffered more or less severely, and four died. The symptoms of the illnesses were, mainly, pain in abdomen, diarrhœa, and vomiting, the diarrhœa being quite unrestrainable; at first the patients complained of coldness, which was accompanied by rigors or shiverings; then followed some degree of fever, the temperature rising to 101°–104° F.; in addition, there was great muscular weakness. Klein exâmined portions of the kidneys of one of those who died, and found in the capillary vessels emboli composed of masses of bacilli. He also examined a portion of the ham, and found the same bacillus. On cultivation of the bacillus and injection into mice, rats, dogs, and guinea-pigs, the same line of symptoms as that found in the persons attacked was manifested.

Hot-baked pork eaten by members of five different households in Nottingham produced the same train of symptoms as the foregoing. Fifteen persons were ill, and one died. The same bacillus as in the Welbeck cases was found in the tissues of the deceased. Glücksman[3] reports the death of one man, and the illness of a second, from eating pickled and smoked pork, due to the presence of the *B. proteus vulgaris* in the meat.

1 *Ann. de l'Inst. Pasteur*, Dec. 1900.
2 Supp. to Tenth Ann. Rep. of Loc. Govt. Bd. for 1880.
3 *Centralblatt f. Bakt*, xxv. No. 20.

Barker[1] narrates the history of a series of persons—twenty-four in all—who were attacked after eating "corned" beef, of whom one died. The beef was contained in "cans" holding 6 lbs. The symptoms were: faintness, giddiness, drowsiness, sickness, great muscular weakness, persistent vomiting, intense frontal headache, colic, diarrhœa, cold and clammy skin, small and rapid pulse, dilated pupils, shallow breathing, and sub-normal temperature. Bacteriological examination of the beef showed the presence of the *B. enteritidis* of Gærtner. Packer[2] records the history of the illness of seven members of a family after partaking of a supper of stewed goose giblets, scraps of goose, and slices of beef. They all took violently ill during the night with purging, abdominal pain, and vomiting, and one boy of fourteen died seven days later. On post-mortem examination of the deceased, intense congestion of stomach and intestines was found. The stomach and contents were examined and analysed for mineral poisons, but none was found; it was, therefore, concluded that the cause was ptomaines. Durham[3] made an investigation into an outbreak of illness caused by eating veal pies which occurred in Oldham in July, 1898, in which 52 persons were attacked, of whom four died. All the fatal cases occurred in those who had partaken of pies which were 48 hours old or older. The cause of the mischief was the growth of Gærtner's bacillus in the pies. Various other outbreaks of poisoning have arisen from other forms of pies, as game-pies and pork-pies. In such cases the cause is likely to be Gærtner's bacillus, or the anærobic *bacillus botulinus* of van Ermengem, the latter of which is not infrequently found in sausages, hence the name *botulismus*.

Brawn[4] has also given rise to toxic symptoms; so also have mutton, as in Glasgow in February 1884, from which two persons died and many suffered,[5] pâté de foie gras,[6] and other articles of meat diet.

Bread.

Hot cross buns caused the illness of over a hundred persons in Inverness, on Good Friday, 1882.[7] Honey occasionally gives rise to illness.[8] It would appear, however, that this is due to the products of poisonous plants gathered by the bees.

Milk and Cheese.

Milk and cheese sometimes contain poisonous products or bacilli, and when consumed in the raw conditions, produce severe poisonous effects. At a school treat at Greenwich in 1899, 60 persons, scholars and teachers, were attacked by violent vomiting and diarrhœa, followed by collapse, after having partaken of Madeira cake and milk. They all recovered. Outbreaks of milk-poisoning are of periodic occurrence at Malta. Zammit[9] has investigated the cause of several of these, and has found it to be the *B. enteritidis sporogenes*, due to

[1] *B. M. J.*, vol. ii. 1899, p. 1367.
[2] Idem, vol. ii. 1900, p. 1372.
[3] Idem, vol. ii. 1898, p. 1797.
[4] Idem, May 10, 1873; vol. i. 1884, p. 1057.
[5] Idem, p. 576.
[6] Idem, 1900, p. 524.
[7] Idem, 1882, vol. i. p. 551.
[8] *Therap. monatschr.*, 12, 1898.
[9] *B. M. J.*, 1900, vol. ii. p. 1151.

accidental contamination. Niven[1] and others have reported similar outbreaks.

Milk epidemics sometimes assume serious proportions in respect of numbers of those attacked. In October, 1901, a severe outbreak took place in Partick, Glasgow, involving about 600 persons of all ages. It was reported to the medical officer of health that many persons were seized with the following symptoms, viz.: violent vomiting, diarrhœa with tenesmus and, in some cases, bloody stools, accompanied by marked prostration. The acute stage of the illness lasted as a rule for 3 or 4 days, but in many cases general lassitude and weakness lasted for a week or more later. On investigation of the facts, Dr. Arbuckle Brown, the medical officer, found that many of the cases occurred on the 8th, and the remainder on the 9th. A few cases, however, happened on the 10th, but they were traced to the same cause as the others. In view of the numbers attacked and the distribution of cases, a common cause was indicated, and the only factor common to all the cases was a common supply of milk from a particular dairy. The dairy was inspected, and found to be in good sanitary condition; the employees were examined and found to be in good health. The farm from which this particular supply of milk came was next inspected, and it was found to be in a good sanitary condition. The farmer, however, stated that one of his cows had sickened on the 7th October, became worse on the 8th, and died on the 9th after the morning milking-time. The milk from this cow on the 7th, 8th, and possibly also on the 9th, was used and sent to the dairy in Partick. The carcase of the cow had been disposed of before the inspection, and the cause of death was not ascertained. An undoubted sample of the affected milk was unfortunately not attainable, but a sample which was alleged to have caused sickness in two adults was examined chemically and bacteriologically with negative results. Consideration of all the facts, however, point to the milk of this cow as the source of the outbreak, and, although exact proof is awanting, to a bacteriological cause.

From the action of the butyric acid bacillus it is believed a toxic substance is formed which has been isolated by Vaughan[2] in the form of needle-like crystals, to which he has given the name of *tyrotoxicon*. Although it is perhaps more commonly found in cheese, there can also be little doubt of its presence at times in ice-cream, milk, and curds. It produces the following symptoms of poisoning, viz.: violent vomiting; urgent and incontrollable diarrhœa; great sickness; thirst; dryness of mouth and tongue; cramps in the legs; and collapse.

Fish, especially when "canned," may cause a similar train of poisonous symptoms; but even when pickled by smoking, they occasionally produce harmful effects. Croudace[3] reports the case of a mother and two children, who half-an-hour after eating a bloater began to feel swollen and itchy about the face, and to have pains in the chest and stomach, followed by vomiting which was violent. There was no diarrhœa. They recovered. Tinned salmon is a comparatively common cause of illness, sometimes fatal;[4] and sardines, also, but perhaps less frequently.[5] In the case recorded by Stevenson where a man died from the effects of eating six sardines, his body after death rapidly developed widespread emphysema. Stevenson, from the fish left in the tin, the vomited matter, and the contents of the stomach recovered alkaloidal extracts, all of which were poisonous to rats.

Shellfish, as oysters, mussels, and cockles, sometimes cause remarkable symptoms after their ingestion. At the Stirling County

[1] *The Lancet*, vol. i. 1895, p. 146.
[2] *The Practitioner*, 1887.
[3] *B. M. J.*, vol. ii. 1897, p. 1771.
[4] Idem, vol. ii. 1891, pp. 84 and 273.
[5] Idem (Stevenson), vol. ii. 1892, p. 1326.

Ball, October, 1895, several persons who had in common partaken of oysters, were suddenly attacked with symptoms of irritant poisoning. For complete information on the subject of the "Cultivation and Storage of Oysters and certain other Molluscs in Relation to the Occurrence of Disease in Man," we must refer the reader to the Report of the Local Government Board, 1896. Poisoning by mussels is now well ascertained to be due to a toxin which is present in the flesh of the living mussel. Brieger has isolated this toxin, to which he has given the name of *mytilotoxin* (from *Mytilus edulis*, the name of the mussel). The symptoms produced are of gastro-intestinal catarrh, accompanied by a sense of oppression in the chest, difficult respiration, skin eruptions, and, in severe cases, by unconsciousness and wide dilatation of pupils. Sir Charles Cameron,[1] Permewan,[2] and others, have recorded cases of fatal poisoning. Doubtless a similar cause may operate after the ingestion of cockles; but in most cases the symptoms are not severe, and are mainly confined to vomiting and "nettle-rash" on skin.

Treatment.—Early evacuation of contents of stomach and free lavage with warm water; stimulants, hypodermically and *per rectum;* hypodermic injections of morphia or strychnia; maintenance of bodily heat; purgative medicines.

Cases of criminal prosecution for poisoning by food are rare. The following case possesses many points of great interest. At the Autumn Circuit Court held in Glasgow in September, 1877, before Lord Moncrieff and a jury, Robert Cochrane, captain of the ship *Crown Prince*, was indicted on the charge of having, while on a voyage between London, Melbourne, Callas, the Falkland Islands, and Queenstown, Ireland, failed to provide the crew with a proper supply of food and drink of a sound and wholesome quality, so that their lives or health were endangered or injured, inasmuch as on 20th Nov. 1876, a quantity of pork in a putrid state was supplied to the crew whereby six persons were shortly thereafter seized with serious illness, the result of blood poisoning, and died at different times during the months of December, 1876, and January, 1877, and seven others were seized with like illnesses and suffered great bodily pain, their lives being endangered and their health being seriously injured. From the evidence, it would seem as if the crew themselves were not unanimously in favour of the view that their illnesses were caused by the pork, but they were agreed that the outbreak was of a mysterious character. At one port during the voyage, because of the illness of some members of the crew who were there conveyed to hospital, fresh men signed articles, and most of them also were seized before they were many days on board. As the ship carried a cargo of guano, some of the men attributed their illnesses to that cause. In any case the crew became alarmed at the mysterious outbreak of illness, and on putting into the Falkland Islands the ship was cleaned and lime-washed. During this time the crew lived on shore, and their health became improved. But the ship had not resumed her voyage a couple of weeks until the crew again began to suffer.

[1] *B. M. J.*, vol. ii. 1890, p. 150. [2] *The Lancet*, vol. ii. 1888, p. 42.

The main symptoms of the illness were these: vomiting and purging which occurred daily, followed sooner or later by numbness and stiffness of hands or feet, or both, accompanied by pains in the limbs and tenderness of the skin, and in the more severe cases by paralysis. In three of the worst cases the men were delirious for three days before their death. One of the officers of the ship more observant than the others arrived at the opinion that the cause of the illness was not the pork, but a certain large barrel of sugar from which the men were supplied for their coffee, and along with their lime-juice. He advised the captain to have the cask re-headed, and a different supply to be given to the men. When the ship arrived at Glasgow, the captain was apprehended on the above charge. Between the date of apprehension and the trial the sugar was submitted to analysis, and it was found by two different analysts to contain 1·65 grains of arsenious acid per pound. Notwithstanding this fact, some of the medical witnesses for the Crown held to the opinion that this was a less likely cause of the illness than the pork, but on the evidence of the late Sir Douglas Maclagan who stated that this proportion of arsenic in sugar which was used daily was not only capable but more likely than putrid pork to produce the foregoing results, the Court directed the jury to return a verdict of not guilty and the accused was liberated.

POISONOUS STINGS, AND EFFECTS OF ACRID JUICES OF PLANTS.

The most common poisonous stings met with in this country are those from dragon flies, bees, and wasps, in addition to that of the common viper which is met with in different parts of Great Britain. The most serious symptoms sometimes arise from wasp stings, and occasionally death itself is produced. Frew has recorded a case in which a young lady of twenty-three was stung behind the angle of the jaw, and in a few minutes after, she felt faint, and then complained of a horrible sensation of choking and of pains over chest and abdomen. The sting had been removed, and ammonia applied. The neck swelled rapidly, and the chest and abdominal pains became agonising. She then became insensible, and died. The whole time which elapsed between the sting and the occurrence of death was not more than 15 minutes. After death the neck and lower part of the face were found much swollen, and the tongue was so much swollen that it filled the mouth so that the throat could not be seen.[1] Cooke narrates another fatal case where the sting was made in the throat of a young lady of twenty-four. She complained of feeling numb all over and of losing her sight; her face turned pallid; and she died in about twenty-five minutes after the sting.[2] A third case, not however proving fatal, is recorded of a medical man who received in quick succession five stings from bees. After intolerable feeling of itching over shoulders and upper chest and back, he found himself getting short of breath, and was forced to lie down; his heart became slow and irregular; the

[1] *B. M. J.*, vol. i. 1896, p. 145.
[2] Idem, vol. ii. 1898, p. 1429. *Vide* also *B. M. J.*, vol. ii. 1900, p. 1437.

respiration rapid, shallow, and laboured; he had symptoms of partial paralysis of the sphincters, as he had great difficulty in preventing the voidance of contents of bowel and bladder; he never lost consciousness, and recovered in about two hours. On the parts of the body which itched, a papular rash appeared.[1] Stings on the tongue have in them an element of danger from the local swelling, apart from any constitutional disturbance. Nott gives the facts of a case in which a boy of thirteen was stung in that part, and in whom the tongue became greatly swollen, hard, tender, and immobile within twenty-five minutes after. No operative interference, however, was necessary, and there were no remote toxic effects.[2]

Discomfort, at least, may be produced by the bites or stings of other insects. Cantlie narrates that while some 200 men of the London Scottish Volunteers were encamped in a Hampshire wood, about one-third of the force were severely bitten by flies, which turned out to be sand flies (a species of *simulium*). Some of the men suffered more than others from the bites of the insect, which were chiefly situated about the knees. One man felt cold and shivery, and his temperature was found to be 102·5° F. The skin of his knees was puffy and painful. His case was typical of some dozens; but in the others, the œdema extended more or less widely from the knees, and in some, the inguinal glands were swollen and tender. Horses also suffered. The insect is somewhat smaller than a house-fly, has a blackish head, thorax, and upper abdominal surface, but is striped black and white on the under abdominal surface, and has clear and transparent wings.[3]

Caterpillars of the "woolly-bear" variety are apt to produce irritation of the skin, shown by erythema and slight œdema. There may also be some rise in bodily temperature. In one case, recorded by the aforenamed observer,[4] four persons were so attacked; they had all been handling caterpillars of the above type which they kept in a box.

Stings of the common viper are not uncommon in certain of the wilder parts of England and Scotland, and in some instances, have proved fatal. Badaloni[5] has shown that in cold weather the sting of this animal is but slightly, if at all, poisonous; but in hot weather, while the animal is active, the physiological effects of the sting upon the human being are more serious. They consist of dilatation of pupil, reduction of bodily temperature, and paralysis, in addition to swelling of the part stung, which is more or less widespread.

Cass recounts the facts of a fatal case of viper bite in a young boy of over four years. The child was bitten between 11 and 12 A.M. on June 8th, but on account of the distance to be traversed before medical aid could be obtained, the child was not seen by him till about 5 P.M. Meanwhile, the father applied to the two small punctures, which were visible on removal of the child's stocking, some carbolic lotion and tar. The boy, at 5 P.M., was found curled up on two chairs, his face hidden under his arm and away from the light, and in a state of abject terror. He looked dull and had been sick many times. His temperature and pupils were normal, his pulse about 100. The bitten leg was intensely swollen as far

[1] *B. M. J.*, vol. ii. 1900, p. 680.
[2] Idem, vol. ii. 1900, p. 1311.
[3] Idem, vol. i. 1900, p. 1023.
[4] Idem, vol. ii. 1899, p. 315.
[5] *The Lancet*, May 5, 1883.

up as the knee, was of a dull white colour, boggy to touch, with occasional dark bluish patches under the skin. The skin was very hot, but not tender to touch. That night he was restless and half comatose, but could be roused by shouting. He had been severely purged, and passed his excretions involuntarily. The temperature was still normal, the pulse, 110. The leg was now swollen up to the groin. The pupils were sluggish. On the 10th he was practically moribund. The temperature was normal; the pulse feeble and very rapid; heart sounds faint; eyes were fixed, pupils slightly dilated, corneal reflex almost gone; respiration was more rapid; purging had ceased, but urine was passed involuntarily. The swelling of limb had fallen. He died at 2 A.M. the following morning.[1]

Russell[2] records the case of a boy aged 14 who, while picnicking in Surrey, was bitten on the thumb by a common adder, but who, after severe illness and extensive swelling of the arm, chest, and neck, eventually recovered.

Skin Eruptions from Acrid Vegetable Juices.—In exceptional instances cases have been recorded in this country of the poisonous effects upon the skin of the acrid juice of *Rhus toxicodendron*. Nicholson[3] and Neale[4] have recorded cases, and Stevenson[5] gives a note on the subject of poisonous effects so produced. Neale states that in the Botanic Gardens, Edinburgh, a student, one day the Professor of Botany was descanting on the poisonous properties of this plant, broke off a twig from the plant, and smeared some of the juice on his left arm. A few days later the whole arm to a point midway between shoulder and elbow became intensely red and swollen, and covered with a pemphigoid eruption, some of the bullæ of which being of the size of pigeons' eggs. Many references to recorded cases will be found in the article noted below.[6]

The Japanese primrose—*Primula obconica*—gives rise to urticaria in certain persons. Neale, in the article quoted, gives the case of a lady who was attacked in this way; and many other observers have recorded similar cases.

In the plant *jequirity*, a leguminous plant, native of Brazil, resides an active principle, which when applied to the conjunctiva in the form of an infusion of the plant in water, produces a peculiar acute inflammation. At first this result was supposed to be due to micro-organisms present in the infusion, but Klein has shown that the bacillus found has nothing to do with the production of the conjunctivitis. The effect is produced by an active principle in the plant itself.

1 *B. M. J.*, vol. ii. 1901, p. 1467.
2 Idem, p. 147.
3 Idem, vol. i. March 4, 1899.
4 Idem, vol. i. 1897, p. 1346.
5 Idem, vol. i. 1897, p. 972.
6 Idem, 1899, vol. i. p. 762.

SECTION III.

PUBLIC HEALTH.

CHAPTER I.

INTRODUCTORY SKETCH.

From the days of the Mosaic Code up till the present time, the science of medicine has been divisible into two distinct branches, viz., the curative, and the prophylactic or preventive. It is interesting to note that in the code above mentioned, probably more attention is devoted to the prophylactic than to the curative aspect, for there are laid down not only the doctrines of quarantine or isolation in infectious disease, disinfection and destruction of infected material, but also the doctrines of preventive medicine in respect of food-supply, more especially with reference to flesh-meat. Indeed, in this last respect, while the reasons of the law-giver respecting the animals whose flesh might or might not be eaten are not clearly given, modern research has demonstrated, that as regards the flesh of the pig, at least, the precautions laid down were salutary. For many centuries these principles have been kept in active use by the Jewish people, and in the Talmud are laid down the regulations whereby only healthy meat may be used in consumption, and suspicious or diseased meat rejected. While in these modern days attempts are being made to secure the like result by inspection of meat in our abattoirs, it is because long and painful experience by the nations has demonstrated its need. If we turn to the Fathers of Medicine—Hippocrates, Galen, Celsus—we find that they were not unmindful of the prophylactic side of the art, and that they recognised the value of fresh air, food, rest, exercise, and other factors in the cure and recuperation of man. In the Middle Ages, however, it would appear as if such principles had been entirely forgotten, or were neglected. People flocked within walled cities for protection, and plague and pestilence followed in their train. Such epidemics, fatal and extensive in their character and incidence, while they had their undoubted origin in the neglect of the very elements of sanitation, were not recognised as due to such neglect, and in those superstitious times were reckoned to be the result of supernatural causes. While such ignorance obtained generally regarding the causal relationship of insanitation and disease, enlightened rulers and physicians arose however from time to time who saw the connection, and who fell back upon the Jewish regulations for the stay of such plagues and pestilences. Bernardo the ruler of Reggio, for example,

was among the first to set in force the Jewish Code when the Black Death broke out in Italy in the fourteenth century, in the course of its devastating progress through the Continents of Asia and Europe. Having started in Asia, it broke out in Italy in 1348, reached England in August of that year, and was in London in November. From this epidemic it has been estimated that in Europe alone it killed twenty-five millions of people. Boccaccio, in the Induction to the *Decamerone*, gives a minute account of its outbreak in Florence, and from his detailed clinical account of the appearances on the bodies of men and animals attacked by it, there can be no doubt of its identity with the Plague.

In the fifteenth century (1485) the Venetian laws of quarantine were framed, the term "quarantine" being derived from the Italian word *quarante* signifying forty, a period of forty days being the period of isolation laid down in the Mosaic Code.

For more substantial advance in sanitary principles, however, we must look to the eighteenth century. Inoculation against small-pox was introduced into England by Lady Mary Montagu in 1722; better ventilation of public buildings and of ships was initiated by Desaguliers and Samuel Sutton; Sir George Baker made researches into the cause and prevention of lead colic; Captain Cook discovered in his voyage round the world the means of preventing scurvy in his ships' crews by the regular use of lime-juice; John Howard did his noble work with reference to the improvement of prisons and gaols—which were then the hot-beds of typhus fever; and, last of all, there was the great discovery by Jenner, in 1798, of the protective influence of vaccine virus against small-pox. As the nineteenth century advanced, and by reason particularly of the first visitation of cholera to Great Britain in 1832, it became necessary that some special sanitary legislation should be enacted. The beginning of the century saw the basis of health statistics established, by Parliament passing an Act for the taking of a census of the inhabitants in 1801. This was only accomplished after nearly fifty years' debate and discussion, as the original proposal to effect this was made by Mr. Thomas Potter in 1753. The census, however, was not complete until 1834, when the poor-law districts were thoroughly revised; hence the first complete statistical figures only date back to the Registrar-General's Returns in 1836. The first outbreak of cholera in this country in 1832, which was imported to Newcastle from Hamburg, and which spread throughout these islands, compelled the attention of the Government, and the Privy Council in that year put in force a measure for preventing the spread of the disease by amending the Quarantine Act. In the same year a Royal Commission on the Poor-Laws was appointed, out of which came the Poor-Law Amendment Act of 1834. In 1833 the Lighting and Watching Act was passed, and also the first amended Factory Act. In 1836 came the Registration Act; in 1840–41, the Vaccination Act; in 1846, the Removal of Nuisances Act; in 1846–48, the Baths and Wash-Houses Act; and in 1847, the Towns Improvement Clauses Act, and the Towns Police Clauses Act. Before this, however, in local Police Acts control was obtained by the authorities of certain populous places

respecting filth—removal, overcrowding, and other like conditions, all of which tended to sanitary improvement. Glasgow, for example, in its Police Act of 1843 obtained these powers. Owing to the labours of Edwin Chadwick with reference to the sanitary condition of large towns, Sir Robert Peel appointed a Royal Sanitary Commission to inquire into the condition of large towns, etc., and the Reports which issued from this Commission caused the passing of the Public Health (England) Act of 1848, and the Nuisances Removal and Disease Prevention Acts, with an amendment of the latter, in the following year. Great Britain experienced its second outbreak of Cholera in 1848–49, and a Board of Health was thereupon constituted to supervise sanitary affairs. It effected the passing of several sanitary measures, viz., the Metropolitan Interment Act of 1850, the Burial Act of 1853, the Common Lodging-Houses Act of 1851–53, and the Metropolitan Water Act of 1852. The third outbreak of Cholera was experienced in 1853–54. Several sanitary measures were thereupon consolidated, viz., the Nuisance Removal Act of 1854, the Diseases Prevention Act of 1855, with amendments in 1860, 1863, and 1866. The Local Government Act was passed in 1858, with amendments in 1861–63; the Adulteration of Foods Act in 1860; the Alkali Works Act in 1863–68; the Sewage Utilisation Acts in 1865–67, Sanitary Acts in 1866, 1868, 1870, with the Sanitary Loans Act in 1869. The Public Health (Scotland) Act was passed on 15th August, 1867, with amendments in 1871 and 1879; and in the year 1867 the Factory Extension Act, with the Artisans' and Labourers' Dwellings Act in the following year. Another Royal Sanitary Commission was appointed in 1869–70, and the principal Sanitary Acts succeeding its work were: The Local Government Board Act, 1871; The Public Health Act, 1872; the Public Health (England) Act, 1875; the Artisans' Dwellings (Scotland) Act, 1875; the Rivers Pollution (Prevention) Act, 1876; the Canal Boats Act, 1877; and the Public Health (Ireland) Act, in 1876, with the Public Health (Water) Act, in the same year. In 1866 the Glasgow Improvements Act was passed, which formed the model for the Artisans' and Labourers' Dwellings Act of Sir Richard Cross (now Viscount Cross). Since that time several new and amending Acts have been passed, in addition to Orders and Regulations, with the provisions of which a Medical Officer of Health must be familiar, in order that he may properly fulfil the duties of his office. The following list may be held to include the various Acts, etc., with which a Medical Officer of Health must have a working knowledge:—

I. Scotland *only*—

(*a*) Public Health (Scotland) Acts, 1891, and 1897;

(*b*) Burgh Police (Scotland) Act, 1892; especially Part IV., which deals with Cleansing, Plans of new Buildings and Regulations, Ventilation, Drainage of Houses, Soil-pipes and Water-closets, Water-supply, Slaughter-houses, —Bye-laws, sects. 316 B, and 318;

(*c*) Vaccination (Scotland) Act, 1863;

(*d*) Dairies, Cowsheds, and Milkshops Orders, 1885, 1887, 1899;

(*e*) Regulations as to Cholera, Yellow Fever, and Plague, 1898;

(*f*) Local Government Acts, 1889.

II. England *only*—

(*a*) Public Health (England) Act, 1875 ;

(*b*) Public Health Water Act, 1878 ;

(*c*) The Cotton Cloth Factories Act, 1889 and 1897 ;

(*d*) Public Health (Amendment) Act, 1890 and 1896 ;

(*e*) Infectious Diseases (Prevention) Act, 1890 ;

(*f*) Local Government Act, 1888 and 1894 ;

(*g*) Isolation Hospitals Act, 1893 (Lord Thring's Act) ;

(*h*) Vaccination Act, 1867 ; and Amending Acts, 1871, 1874, and 1898 ;

(*i*) Canal Boats Acts, 1877 and 1884 ;

(*j*) Public Health (Interments) Act, 1879 ;

(*k*) Regulations as to Cholera, Yellow Fever, and Plague, 1896 ;

(*l*) Public Health (Ports) Act, 1896 ;

(*m*) Dairies, Cowsheds, and Milkshops Orders, 1885, 1887, and 1899 ;

(*n*) Model Bye-laws issued by Local Government Board.

Sanitary Acts for the Metropolis of London, while passed separately, embody the provisions of the foregoing.

III. United Kingdom—

(*a*) Factories and Workshops Act, 1878 ;

Part I. (1) Sanitary provisions ;
,, II. (1) Sections 4 and 5 ;
,, IV., including first and second schedules ;

(*b*) Factories and Workshops Acts, 1883, 1891, and 1895, in so far as they amend or extend sanitary provisions and provisions respecting health ;

(*c*) Sale of Food and Drugs Acts, 1875 to 1899 ;

(*d*) Margarine Act, 1887 ;

(*e*) Sale of Horse-Flesh Regulation Act, 1889 ;

(*f*) The Alkali Acts, 1881–1892 ;

(*g*) Housing of the Working-Classes Act, 1885 and 1890 ;

(*h*) Contagious Diseases (Animals) Acts, 1878—section 34 ;
,, ,, ,, ,, 1886—section 9 ;

(*i*) Diseases of Animals Act, 1894 ;

(*j*) Infectious Diseases (Notification) Act, 1899 ;

(*k*) Rivers Pollution (Prevention) Acts, 1876 and 1893 ;

(*l*) The Bakehouse Regulation Act, 1863 ;

IV. Ireland—

(*a*) The Public Health (Ireland) Act, 1874 ; and others, embodying the principles of the foregoing Acts.

DUTIES OF A MEDICAL OFFICER OF HEALTH.

The appointment of Medical Officer of Health in England is laid down in section 189 of the Public Health Act of 1875, and sect. 191 enacts that no person shall be appointed to this office unless he is a legally qualified medical practitioner, and if appointed after 1st Jan. 1892 to a district of 50,000 inhabitants or over, unless he is the possessor of a registered degree or diploma in public health, hygiene, or sanitary science. The Local Government Board

has certain powers respecting the appointment, duties, salary, and tenure of office of this official, where any portion of his salary is paid by moneys voted by Parliament. The medical officer to a union may be appointed medical officer of health to his rural sanitary district, although he does not possess any registered sanitary degree or diploma, and a medical officer of health may be appointed to act as a sanitary inspector, subject to the approval of the Board. In Scotland, the appointment is compulsory upon counties by section 52 of the Local Government (Scotland) Act, 1889 ; and section 54 enacts (1) that he shall be a registered medical practitioner, (2) that after 1st Jan. 1893, where the population of a county, district, or parish is 30,000 or upwards, he shall be registered as the holder of a qualification in sanitary science, public health, or state medicine, and (3) that he shall be removable from office only with the sanction of the Scottish Local Government Board. In burghs, under section 77 (1) of the Burgh Police Act, 1892, the medical officer must be in possession of a registered qualification in public health.

In England, the duties of this official are laid down in the Order of the Local Government Board, March, 1891 ; they are as follow :—

1. He shall inform himself as far as practicable respecting all influences affecting, or threatening to affect, injuriously the public health within the district.

2. He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

3. He shall, by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

4. He shall be prepared to advise the Sanitary Authority on all matters affecting the health of the district, and on all sanitary points involved in the action of the Sanitary Authority ; and in cases requiring it, he shall certify for the guidance of the Sanitary Authority or of the justices, as to any matter in respect of which the certificate of a medical officer of health or a medical practitioner is required as the basis or in aid of sanitary action.

5. He shall advise the Sanitary Authority on any question relating to health involved in the framing and subsequent working of such bye-laws and regulations as they may have power to make, and as to the adoption by the Sanitary Authority of the Infectious Disease (Prevention) Act, 1890, or of any section or sections of such Act.

6. On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit the spot without delay, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measures for the prevention of the disease as he is legally authorised to take under any statute in force in the district, or by any resolution of the Sanitary Authority.

7. Subject to the instructions of the Sanitary Authority, he shall direct or superintend the work of the inspector of nuisances in the way and to the extent that the Sanitary Authority shall approve, and on receiving information from the inspector of nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorised to take under any statute in force in the district, or by any resolution of the Sanitary Authority, as the circumstances may justify and require.

8. In any case in which it may appear to him to be necessary or advisable, or

in which he shall be so directed by the Sanitary Authority, he shall himself inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, and any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, exposed for sale, or deposited for the purpose of sale, or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be dealt with by a justice according to the provisions of the statutes applicable to the case.

9. He shall perform all the duties imposed upon him by any bye-laws and regulations of the Sanitary Authority, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorised to frame bye-laws and regulations.

10. He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

11. He shall attend at the office of the Sanitary Authority or at some other appointed place, at such stated times as they may direct.

12. He shall from time to time report in writing to the Sanitary Authority his proceedings and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been enabled to ascertain the same.

13. He shall keep a book or books, to be provided by the Sanitary Authority, in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon, and of any action taken on previous reports; and shall produce such book or books, whenever required, to the Sanitary Authority.

14. He shall also make an annual report to the Sanitary Authority up to the end of December in each year, comprising a summary of the action taken, or which he has advised the Sanitary Authority to take, during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious to health existing in his district, and of the proceedings in which he has taken part or advised under any statute, so far as such proceedings relate to those conditions; and also an account of the supervision exercised by him, or on his advice, for sanitary purposes, over places and houses that the Sanitary Authority have power to regulate, with the nature and results of any proceedings which may have been so required and taken in respect of the same during the year. It shall also record the action taken by him, or on his advice, during the year, in regard to offensive trades, to dairies, cowsheds, and milkshops, and to factories and workshops. The report shall also contain tabular statements (on forms to be supplied by the Local Government Board, or to the like effect) of the sickness and mortality within the district classified according to diseases, ages, and localities. Provided that if the Medical Officer of Health shall cease to hold office before December 31, in any year, he shall make the like report for so much of the year as shall have expired when he ceases to hold office.

15. He shall give immediate information to the Local Government Board of any outbreak of dangerous epidemic disease within the district, and shall transmit to the Board a copy of each annual report and of any special report. He shall make a special report to the Board of the grounds of any advice he may give to the Sanitary Authority with a view to the closure of any school or schools, in pursuance of the Code of Regulations approved by the Education Department, and for the time being in force.

16. At the same time that he gives information to the Board of the outbreak of infectious disease, or transmits to them a copy of his annual or any special report, he must give the like information, or transmit a copy of such report, to the County Council of the county in which his district is situated.

17. In matters not specifically provided for in this order he shall observe and execute any instructions issued by the Local Government Board, and the lawful orders and directions of the Sanitary Authority applicable to his office.

18. Whenever the Local Government Board shall make regulations for all or any of the purposes specified in section 134 of the Public Health Act, 1875, and shall declare the regulations so made to be in force within the area comprising the whole or any part of the district, he shall observe such regulations, so far as the same relate to or concern his office.

The duties of a Port Medical Officer of Health are essentially on the same lines as the foregoing, but different terms are employed by reason that ships, harbours, crews, etc., are being specially dealt with, and not houses and districts.

In Scotland, prior to the passing of the Public Health Act of 1897 and the Local Government Act of 1894, Bye-laws regulating the duties of the Medical Officer of Health were issued by the Board of Supervision, of date 28th July, 1873. These were, as far as they went, identical with those of the English Board. By section 15 of the Public Health Act of 1897, this duty of regulating the duties of medical officers and sanitary inspectors and their relations to each other is vested in local authorities, subject to the approval of the Board.

In Ireland, the position of the Medical Officer of Health is regulated by section 10 of the Public Health (Ireland) Act, 1874, which enacts that every medical officer of a dispensary district shall be a sanitary officer for such district or for such part thereof as he shall personally be in charge of, with such additional salary as the Sanitary Authority may determine subject to the approval of the Local Government Board. Every sanitary authority in Ireland must appoint (*a*) a consulting sanitary officer, (*b*) an *ex-officio* sanitary officer, who is the medical officer of a dispensary district, and (*c*) when thought necessary or advisable, a medical superintendent officer of health.

The duties of the Medical Officer of Health in Ireland are the following :—

1. He shall inquire into any matter which is brought under his notice by the sanitary sub-officer (or sanitary inspector).
2. He shall attend to and inquire into any matter brought under his notice by the executive sanitary officer, or clerk.
3. He shall report to the Sanitary Authority on any matter which should be brought under their notice, and he shall, from time to time, furnish statistical returns to the Local Government Board, of disease, etc.

In order to fulfil the duties expected of him, the Medical Officer of Health on appointment to a rural district in Ireland, ought, as a preliminary, to make himself acquainted with various points which may be classified under two main heads, viz. :—

I. Natural Conditions ;
II. Artificial Conditions ;

in respect of their action on the health of the inhabitants.

Under the former head, he should know the main facts regarding (*a*) the *Topography* of his district ; such as its mean height above the sea-level, and its maximum and minimum heights ; and the nature of the soil ; (*b*) *Geology*, with relation to the quality and quantity of water-supplies from impounded reservoirs, natural collections of waters, and wells ; existence of sand or gravel tracts for interment purposes ; and the like ; (*c*) *Meteorology*, with respect to force, direction, and prevalence of winds, mean rainfall, barometric pressure, etc. ; (*d*) *Ex-*

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isting provisions for Water-Supply, with respect to sources, having regard to possible impurity in well-supplies, or, if from streams, of the likelihood of contamination in their course; its quality and quantity, with reference to improvement or extension of supplies; (*e*) *Drainage and Sewerage*; (*f*) *Habits of the Population* with respect to cleanliness or the opposite, overcrowding, etc.; (*g*) *Mode of Disposal of Night-Soil and House-Refuse.* In view of the milk traffic from rural districts to urban, it will be part of his work to discover the source of water-supplies of dairy farms, from the point of view of possible contamination.

The second group of conditions are mainly found in urban or populous districts, due to the congregation of Man in large centres, and it comprises among others the following subjects, viz.:—

(*a*) The houses in which the population lives;
(*b*) The water-supply;
(*c*) Disposal of sewage, and house-drainage arrangements;
(*d*) Effects of trade processes, offensive trades, factories, etc., upon health.

In order that he may comply with the duty of providing the requisite returns of the mortality of his district, it is absolutely necessary that the medical officer should have thorough knowledge of the statistics of his district, which facts he may obtain from the census returns and from the registrars of his district.

Census of Countries of the World, – Century Magazine Oct. 190[illegible].

CHAPTER II.

VITAL STATISTICS AND STATISTICAL RETURNS.

One of the important duties of the Medical Officer of Health is that which deals with disease in its statistical aspects. Without an accurate knowledge of the population of his district, therefore, returns made by him will lose their value because of their inaccuracy. By means of previous census returns, a knowledge may be gained of the increase or decrease of population within the district, but for instituting tabular returns, such as birth-rates, death-rates, etc., it is requisite that the population of the year under which they are given should be known either absolutely or by computation.

Population.—Since the year 1801, a decennial return has been made of the population of these islands, but it was not till the return of 1881 that age and sex distribution was given. At census periods, therefore, is the actual population only definitely and accurately known; between these periods the population is estimated.

Estimations of populations are liable to inaccuracy, nevertheless they must be calculated for statistical purposes. *The estimate for any intercensal year is made on the assumption that the rate of increase or decrease in a given population, as ascertained by the two previous census returns, continues uniformly the same.* This assumption may be near or very far from the mark. For example, the death-rate of Liverpool, based on the population of the census of 1881, was shown to be 26·7 per thousand; and on the assumption that the population had gone on increasing in the same ratio which obtained between the census figure of 1871 and that of 1881, the population in 1890 was accordingly estimated to be relatively greater and the death-rate worked out at 23·6 per thousand; but when the census figure of the population for 1891 was announced, it was seen that the population instead of increasing had decreased, and that the death-rate figure of 23·6 per 1000 returned for 1890 should have been 27·8 per 1000. The population of Glasgow was estimated by the Registrar-General to be in June 1900, 743,969, but the census of the year 1901 showed the figure to be 760,406. Many other instances might be given where, on the other hand, the population was under-estimated. However, the above method is that employed by the Registrars-General, and, therefore, demands some further explanation. Given, therefore, the population of a given district at a fixed date, to find the population after a given number of years thereafter. The main normal factor in the increase of any population is the excess of annual births over the annual deaths—not reckoning, for the moment, the elements of immigration.

Let us suppose that this rate of increase per unit is represented by r, then at the end of the first year the increase will be represented by $1+r$; it will equal—

At the end of the second year $=(1+r)^2$
" " third " $=(1+r)^3$
" " fourth " $=(1+r)^4$
" " fifth " $=(1+r)^5$
and so on till the tenth, $=(1+r)^{10}$
or the n^{th} year $=(1+r)^n$.
Let $R=1+r$
Let P = the population of one census.
Let P^1 = the population of the next following census.

Then if r = annual increase per unit, and $R=1+r$ = annual increment of each unit per annum, then—

$P+(1+r)^n = PR^n = P^1$.
But $n=10$ in this case.
$\therefore PR^{10}=P^1$. Hence the logarithm of $P + 10 \log. R = \log. P^1$.
And $10 \log. R = \log. P^1 - \log. P$.
$\therefore \log. R = \frac{1}{10}(\log. P^1 - \log. P)$.

We quote the following working example from Newsholme[1]—

If the census population of a town is 32,000 in 1871, and 36,000 in 1881, what is the mean population in 1885?

$1871 = P = 32{,}000 =$
$1881 = P^1 = 36{,}000 =$
Log. of P^1 = log. of 36,000 = 4·556303
Log. of P = log. of 32,000 = 4·505150
$\therefore \log. P^1 - \log. P = 0{\cdot}051153$

And $\frac{1}{10}(\log. P^1 - \log. P) = 0{\cdot}051153 \div 10 = 0{\cdot}005115 = \log. R = \log. 1+r$.
$\therefore R = 1 + r = 1{\cdot}10118$.
$n = 1885\frac{1}{2} - 1881\frac{1}{4} = 4\frac{1}{4}$ years, since the mean population of any year is that of the middle of the year, and since the census is taken at the end of the first quarter.

In the above problem, therefore—

$P^1 = PR^n$, where $P = 36{,}000$,
" $R = 1{\cdot}0118$,
" $n = 4\frac{1}{4}$ years.

$$\therefore P^1 = \text{Pop. required} = 36{,}000 \times (1{\cdot}0118)\frac{17}{4}.$$

$$\text{And } \log. P^1 = 36{,}000 + \frac{17}{4} \log. 1{\cdot}0118.$$

But log. of 1·011 = 0·005115.

$$\therefore \frac{17}{4} \log. 1{\cdot}0118 = 0{\cdot}021739$$

Log. of 36,000 = 4·556303

Therefore by addition, log. P^1 = 4·578042

Log. 4·578042 = 37,848 = the required population of 1885.

From the foregoing, it will be seen that the increase of population is calculated as a geometric increase, and not as an arithmetic increase. This will be more apparent if we work out the same problem on the simple arithmetic increase—

Population of 1881 = 36,000
" " 1871 = 32,000
Total decennial increase = 4,000.
Annual increase = 4,000 ÷ 10 = 400.

$$400 \times \frac{17}{4} + 36{,}000 = 37{,}700 = \text{the required population of 1885.}$$

There are other methods, however, of ascertaining an intercensal population—

A. By adding to or subtracting from the product of the difference between the total births and the total deaths since the last census return, the balance of immigrants and emigrants.

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[1] "Vital Statistics," 1st ed., p. 6.

This is likely to be inaccurate, because there is no means of knowing, at least in this country, the number of persons who enter or leave a given area within a given time.

B. By ascertaining the number of inhabited houses within the area, and multiplying the figure found by the average number of persons per house as ascertained from the last census.

This method is fairly accurate as a working basis in populations where the inhabited houses are reckoned annually for assessment purposes, but, as has been pointed out, it is liable to be fallacious where in new suburbs large numbers of houses are rapidly run up, and where these are occupied by newly-married persons.

Indeed it may be said that all the methods of estimating intercensal populations are liable to error for various reasons, and the approximate truth can only be arrived at by the use of all the available means.

Having ascertained the total population, the next step is to sort it out into ages. This is called the *Age-Distribution* of a population, and has been given by the Registrar-General since the census return for 1881. For statistical purposes, it is supposed to remain constant for all ages from one census period to the next. It is important that the age-distribution should be ascertained, since the death-rates of infancy and old age are considerably higher than those of intermediate ages, and because populations differ as to the numbers of persons living at these ages. It may be taken as a general fact that rural populations contain a larger proportion of persons at the extremes of life than do town or urban populations.

Sex-Distribution.—Owing to the lower death-rates which prevail in the female sex, except between the ages of 10 and 15, the existence of a large proportion of females in any population tends to lower the general death-rate. This is true of suburban, factory-town, and watering-place populations, where a large number of female domestic-servants and factory-hands compose the population.

Density of a Population.—The denser the population in a given area the higher will be the general death-rate, under ordinary circumstances. This has been abundantly proved from the experience of populous places.

This is seen, for example, in the death-rates per 1000 of the following Glasgow Districts for 1899 :—

TABLE I.

District.	Number of Persons per Acre.	Death-rate per Thousand.
Kelvinside	9	6·47
Hillhead	12	9·66
Blythswood	107	15·60
High Street (West Side)	242	26·66
Cowcaddens	280	32·66

The average density of any given population is arrived at by dividing the total number of the inhabitants by the area covered by their habitations. Thus the density is reckoned as so many persons per acre, or square mile, or by any other unit of space. The actual density is

obtained by ascertaining the precise number of inhabitants living within a certain defined and measured area. Hence the average density may be no true guide to the actual densities in a given population, since the most densely and most sparsely populated districts are averaged together, as are also the most open and most crowded spaces. In like manner the number of rooms in a house has an effect on the health of its population; generally speaking, the smallest houses, which give the highest death-rates, are those which are occupied by persons whose struggle for existence is the hardest.

Vicious habits of certain classes of population produce fruits in high infantile mortality, shortened lives generally, and in high death-rates. This might be demonstrated in many ways, but the following table of the actual conditions which existed in one of the worst districts of Glasgow will suffice to make every point clear. In this district 50 per cent. of the houses are "ticketed," that is, they are liable to be inspected at any hour of night or day for the existence of overcrowding. The population largely consisted of the immoral, criminal, and lazy classes.

Table II.

Effects of Uncleanliness and Vicious Habits on Health of Population.[1]

Glasgow District.

	Worst.	Best.	Average of City.
~~Death~~-rate per 1000 of population	30·49	26·14	34·92
Death-rate " "	32·45	13·89	20·91
Uncertified deaths	18·5%	3%	5·7%
Infantile death-rate (per 1000 born)	239	88	133
Illegitimacy	25%	3%	8%
Premature births (per 100 children born)	41	12	17·5
Inferior houses (ticketed)	51%	1·4%	18%
Providence (as shown by insurance in Friendly Societies)	40%	70%	56%
Demands on sanitary staff (per 100 of population)	231%	55	84%
Born on rates and charity—			
Hospital	10%	...	3%
Out-door	45%	...	22%
Vaccinated by rates and charity	50%	...	25%
Treated in sickness by—			
Rates	25·4%	...	10·6%
Charity	4·3%	...	4·9%
Spent in food	50%	..	Unknown.
Spent in drink	50%	...	"

[1] "The Cleansing Department is largely occupied in sweeping-up and removing filth which is thrown over the windows and deposited about the courts. There are men employed doing nothing else but going round these courts and closes every few hours throughout the day with brush and hose and water-pail, and yet they are never clean." This district "furnishes the greater part of the work of the Central Police Court." *Vide* paper on "Sanitation and Social Economics," by Dr. J. B. Russell, Medical Officer of Health, Glasgow, *Transactions of Phil. Soc. of Glasgow*, vol. xxi.

The contrast will be shown even better by comparing this very bad district with another district in Glasgow in which the density of population is greater, where the percentage of one- and two-roomed houses is identical, but which is inhabited mainly by the industrious artisan classes.

TABLE III.

	St. Rollox. District IV.	Bridgegate and Wynds. District XIV.
Population	14,211	7,775
Density per acre	316 persons	222
Total births	654	299
Total deaths	310	295
Birth-rate	46 per 1000	38·5
Death-rate	21·8 ,,	37·9
Number of deaths under five	132	131
Percentage of deaths under five to total deaths	43	44

Within the last few years, however, this unhealthy district (XIV.) has been completely changed for the better; old houses have been pulled down by streets; new and wider streets have been formed; and, generally, by the substitution of new houses and free air-spaces, its high mortality has disappeared.

But even density of population and the operation of other adverse factors are not always productive of the highest death-rate in a mixed population. If we take the death-rates per million from phthisis and acute pulmonary diseases as our test, density of population alone does not appear to be the principal factor. For example: in the St. Rollox district of Glasgow, where the density has now risen to 368 persons per acre, and in that of Cowcaddens, where it is only 280 per acre, the number of deaths per million from these diseases in the former was 4957, whereas in the latter it was 11,548, notwithstanding the fact that in the centre of the former is one of the largest chemical works in the world, and many large engineering and other works. Moreover in 1898 the general death-rate from all causes was in the former 19, and in the latter 32 per thousand per annum.

That mere density of population is not the lethal factor in a picked population which it is in a mixed and vicious population, is shown by the statistical history of the Peabody and Artisans' Block Buildings of London, where the density is 750 persons per acre. In 1884, these properties, consisting of 10,144 apartments, occupied by 18,453 persons, showed a birth-rate of 44·6 per 1000, or 10·9 higher than the general London rate; a death-rate of 19·1 per 1000, or 1·2 less; and an infantile mortality of 138·7 per 1000 births, or 13·7 less than the London average. On the general question of density Newsholme[1] says very properly: "It would be a mistake to suppose that the ratio of density to mortality demonstrated by Dr. Farr is an inexorable law incapable of mitigation. The fact that the urban is generally decreasing in spite of increasing density, and is decreasing at a more rapid rate than the rural death-rate, is a disproof of this." Ogle has shown in his figures

[1] *Op. cit.* p. 143.

of the relation of density of population to mortality rates, that until the figure reaches 400 persons per square mile density is not an important factor.

Birth-Rate.—The birth-rate of a population is calculated from the number of births in the year as a rate per 1000 of the population living at the middle of the year:—

$$\frac{\text{Number of births in the year}}{\text{Population in middle of year}} \times 1000 = \text{Birth-Rate.}$$

This is but an imperfect way of reckoning, since it takes no special count of the number of persons living at child-bearing ages, a figure which obviously will vary in different populations. A more accurate way would be to calculate the rate from the number of women in a population within the years of child-bearing. But even this could only properly be designated as a *live birth-rate*, since no count is taken of still-births; therefore, a birth-rate must not in any case be reckoned as a *fecundity*-rate, even although the eventual figure might not be much different by the inclusion of the still-births. The illegitimate birth-rate is worked out in the same way.

The Effect of a High Birth-Rate upon the Death-Rate.—This has been a much-debated question for many years, and statisticians have been divided in opinion on the subject; but the following statement may be taken as fairly expressive of the effect of a high birth-rate upon the death-rate of communities under different circumstances: where a high birth-rate suddenly obtains from a sudden influx of young married persons to a community, by reason of employment or otherwise, the effect is undoubtedly to raise the death-rate, because of the relatively much higher mortality in infants under one year than at any other age-period. But should this high birth-rate be maintained continuously over a series of years, the result will be that the general death-rate is lowered, because its continuance contributes to the sum of those lives at ages at which mortality is lowest. Where the birth-rate on the other hand is lower than the average, it is contributory to an increase in the death-rate, for the reasons above given. It is a significant fact that since 1876 in England and Wales the birth-rate has progressively declined. In that year it stood at 36·3 per 1000, and in its progressive fall it reached in 1899 the figure of 29·2, and in 1900 for the whole kingdom, 29 per 1000 of population. This last fact indicates in a total population of 41½ millions an annual deficiency in children since 1875 of about 250,000. In Scotland the same lowered birth-rate is found, and that notwithstanding the continued maintenance in ratio of the marriage-rate. In 1861–70 the birth-rate per 1000 was 35, in 1871–80, 34·86, in 1881–90, 32·30, and in 1891–90, 30·70. In all the counties of Scotland, except Kincardine, Nairn, and Kinross, it has declined between 1880 and 1899; and in Roxburgh, Clackmannan, and Selkirk the decrease has been very considerable. There can be little doubt that the main reason for this decline is due to prevention of conception by married persons.

The Marriage-Rate, as usually returned, is calculated from the annual marriages divided by the total population, and the product multiplied by 1000; it is, therefore, a ratio per 1000 of population, thus:—

$$\frac{\text{Annual number of marriages}}{\text{Total population}} \times 1000 = \text{Marriage-Rate.}$$

Marriages are relatively more frequent in urban than in rural communities, chiefly because the sexes at marriageable ages are attracted to the populous centres by facilities of remunerative employment. It has been suggested that the rate would be better expressed as the product of the annual marriages divided by the population of both sexes above the age of fifteen, and the product multiplied by 1000.

Death-Rates.—The annual death-rate of a population is reckoned from the number of deaths in the year divided by the population in the middle of the year and the answer multiplied by 1000, thus:—

$$\frac{\text{Number of deaths in the year}}{\text{Population at middle of the year}} \times 1000 = \text{Death-Rate.}$$

But weekly, monthly, and quarterly death-rates in terms of 1000 per annum are also returned in statistical reports. The first is obtained by dividing the mean annual population by 52·17747, the exact number of weeks in a year, and thus arriving at the weekly population, by which the number of weekly deaths is divided; the product multiplied by 1000 gives the weekly death-rate in terms of 1000 per annum, thus:—

$$\frac{\text{Number of deaths in the week}}{\text{Mean population} \div 52{\cdot}17747} \times 1000 = \text{Weekly Death-Rate per 1000 per annum.}$$

The monthly rate is obtained by dividing the mean annual population by 365·24226, the exact number of days in a year, multiplying the product by the number of days in the month the rate of which is wanted. This gives the monthly population. Then the number of deaths in the month is divided by the monthly population, the product multiplied by 1000, and the answer is the monthly death-rate in terms of 1000 per annum, thus:—

$$\frac{\text{Number of deaths in the month}}{\text{Mean population} \div 365{\cdot}24226 \times \text{number of days in month}} \times 1000 = \text{Monthly Death-Rate per 1000 per annum.}$$

The quarterly death-rate is obtained by a similar process, except that the daily population got as described is multiplied by the number of days in the quarter, to get the quarterly population, which when calculated into the number of deaths in the quarter and multiplied by 1000, gives the quarterly death-rate in terms of 1000 per annum.

Corrections of Crude Death-Rate.—The death-rate so obtained is the *general* or *crude* death-rate, but it is susceptible of various corrections. Thus in any large population in which there are public institutions frequented by persons non-resident in that population, the deaths of such cannot be fairly debited in the returns of that population, and therefore must not be reckoned as part of the death-toll; in like manner the deaths of residents which take place outside the area must be included.

The second correction is that for sex and age distribution. As has already been stated, any population with an unusually large number of units at the extreme ends of life will have a higher death-rate than an average mixed community, and one having an unusual preponderance of females, a lower death-rate. In order, then, to make the death-rates of such places comparable with those of other places, corrections must be made for the incidence of age and sex. The Registrar-General

gives factors for the principal populations, based upon these factors as ascertained at the previous census. These factors are obtained from the mean annual death-rate of the country for the decade prior to the last census for each age and sex, and calculated into the age and sex distribution of the area according to last census. The total deaths thus calculated, multiplied by 1000, and divided by the population of the last census, gives the *standard death-rate*. The mean annual death-rate of the country divided by the standard death-rate gives the *factor for correction*, which multiplied by the *recorded death-rate* gives the *corrected death-rate*. The factor for correction is, in most cases, greater than unity. The *comparative mortality figure* is obtained by multiplying the *corrected death-rate* by 1000 and dividing by the death-rate for the whole country.

An example, which we quote from Newsholme,[1] will illustrate how these factors are obtained.

TABLE IV.

Ages.	Mean Annual Death-Rate of England and Wales 1881–90, per 1000 living at each Group of Ages.		Population of Huddersfield in 1891.		Calculated Number of Deaths in Huddersfield.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5 . .	61·59	51·95	4551	4785	280	249
5— . . .	5·35	5·27	4691	5081	25	27
10— . . .	2·96	3·11	5113	5165	15	16
15— . . .	4·33	4·42	4905	5549	21	25
20— . . .	5·73	5·54	4541	5461	26	30
25— . . .	7·78	7·41	7466	8834	58	65
35— . . .	12·41	10·61	5576	6265	69	66
45— . . .	19·36	15·09	3944	4649	76	70
55— . . .	34·69	28·45	2393	3017	83	86
65— . . .	70·39	60·36	1128	1590	79	96
75 and upwards .	162·62	147·98	250	466	41	69
Totals . .			44,558	50,862	773	799
			95,420		1,572	

The *standard* death-rate for Huddersfield in 1891 thus works out :—

$$\frac{1572 \times 1000}{95{,}420} = 16{\cdot}47 \text{ per } 1000.$$

The annual death-rate for England and Wales in 1881–90 was 19·15 ; therefore the *factor* for *correction* for age and sex for Huddersfield is $\frac{19{\cdot}15}{16{\cdot}47}$ = 1·1627 ; in other words, the age and sex distribution in that town was much more favourable to a low death-rate than in the rest of England. The *corrected* death-rate for Huddersfield is, therefore, the *recorded* death-rate (16·40) multiplied by the factor for correction ; thus 16·40 × 1·1627 = 19·068, or 19·07 per 1000 per annum. The comparative mortality figure for that town is the corrected death-rate of the town, viz. : 19·07, compared with the recorded death-rate at all ages in England and Wales in the same year, viz , 17·43, taken as 1000,

$$\text{thus } \frac{19{\cdot}07 \times 1000}{17{\cdot}43} = 1094.$$

[1] *Op. cit.* p. 110.

/ 1,572
/ =

Having ascertained the general death-rate of the community, death-rates according to sex, to age, and to certain classes of disease must be made out in order to indicate the conditions which bear upon life.

Death-Rates of Age-Groups.—The age-groups for which rates are calculated are twelve in number, viz.:—

Under one year—	5—	10—	15—	20—	25—	35—	45	55—	65—	75—	85 and upwards.

It may be said, generally, that the death-rates of the age-groups under 5 and over 55 are higher than the general death-rate for all ages; that the rate between 10–15 is the lowest; while between 5 and 25 the rate is lower than that at later ages.

Infantile Mortality.—This is reckoned by dividing the number of deaths of infants under one year by the number of births registered during the year, and multiplying the product by 1000, thus:—

$$\frac{\text{Deaths of children under one year}}{\text{Births registered during the year}} \times 1000 = \text{Infantile Mortality.}$$

The incidence of infantile mortality varies in different populous centres, the chief determining factors being the physical well-being of the mothers and the care exercised in the upbringing of the infants. The increasing tendency to feed artificially by bottle milk or artificial foods infants who, under other circumstances of social life, would have been nursed by the mothers themselves, doubtless contributes its share to the infantile death-toll, but the other factor, that due to the employment of young mothers in factories and other trade processes, has probably a larger influence. In 1899, in Glasgow, 3686 children under one year died, and that figure formed 24 per cent. of the deaths at all ages. The chief contributory causes of death were these:—

Diarrhœa	=	16	per cent.
Respiratory diseases	=	20	,,
Premature births	=	13	,,
Nervous diseases	=	7	,,
Measles	=	3	,,
Whooping-cough	=	3	,,
Unclassified causes	=	26	,,

Infantile mortality would appear to be on the increase, as indicated below:—

TABLE V.

Populous Place.	Death-rate per 1000 births.		
	1888–97.	1898.	1899.
Glasgow	146	156	152
Edinburgh	140	144	151
Dundee	176	182	170
Liverpool	189	184	198
Aberdeen	141	158	143
Manchester	185	197	206
Birmingham	180	191	191
Leeds	178	182	171
Sheffield	180	195	194

For any age-group, the death-rate is obtained by dividing the number of deaths in the group by the number of persons living at the same ages, and multiplying the product by 1000. In this way the total deaths in a population may be divided into the twelve age-groups given, and the death-rates therefor accordingly calculated.

The proportion of persons living at different age-groups will be seen in the following table :—

Table VI.

Table of Age-groups per 1000 *Population of England and Wales in* 1895.

Ages.	Persons.
Under 5	120
5—15	228
15—25	196
25—35	147
35—45	113
45—55	87
55—65	59
65—75	35
75—85	13
85 and upward	2
	1000

The percentage proportion of deaths at each age-group is as follows :—

Ages.	Deaths per cent.
Under 5	37·4
5—10	2·9
10—15	1·6
15—20	2·3
20—25	2·7
25—35	5·8
35—45	7·0
45—55	8·1
55—65	9·8
65—75	11·8
75—85	8·5
85 and upward	2·1
	100·0

Death-Rates of the Sexes.—At birth, the number of males is greater than that of females, but at all other ages, except between 5 and 14, females preponderate in numbers, and taking the mean of all ages there are 1060 females in the population of Great Britain to every 1000 males. At all ages the expectation of life of a female is greater than that of a male ; consequently in any population in which the proportion of females to males is higher than the normal, the death-rate is correspondingly lowered. If we differentiate, therefore, between the death-rate of the sexes, it will be found that except between the ages of 10 and 25 the female death-rate will be lower than the male. In England and Wales in the decade 1881–1890, the former was 18·1, and the latter 20·2 per 1000 per annum.

TABLE VII.—GLASGOW, 1881–90.

Average Annual Mortality per 1000 living at Different Age-groups:—

Ages.	Males.	Females.
0—5	86·24	75·52
5—10	10·65	10·14
10—15	5·52	5·33
15—20	7·24	7·13
20—25	7·93	8·94
25—35	9·34	10·99
35—45	15·28	14·25
45—55	26·50	21·54
55—65	45·81	38·42
65—75	84·31	70·21
75—85	149·47	123·75
85—95	262·17	221·08
95 and upwards	260·87	300·00
All ages	25·01	23·66

In like manner death-rates may be calculated for Diseases or Groups of Diseases. As an indication of the sanitary condition of a district, a special return is made called the *Zymotic Death-rate.* This, however, only includes the deaths from the seven principal zymotic diseases, viz.: small-pox, measles, scarlet fever, fever (which includes typhus, simple, combined, and enteric), diphtheria, whooping-cough, and diarrhœa, and omits returns of deaths from erysipelas, puerperal fever, and others; thus the zymotic death-rate does not conform to the diseases scheduled in the Infectious Diseases (Notification) Act. It ought, therefore, to be clearly understood that the zymotic death-rate, as presently computed, is not a correct return of the death-rate from all zymotic diseases; but, at the same time, it is a valuable index of the health-conditions of a district. It may be computed and returned in more than one way, viz.: (1) *as a proportion of deaths to numbers attacked*; (2) *as a proportion of deaths to the total deaths*; (3) *as a proportion of deaths from each zymotic disease per thousand or million of population.*

The value of the first method will entirely depend on the number of units from which the calculation is made; the larger the number the nearer the result to the truth, the smaller, the reverse. The second method shows the proportion of deaths from these diseases to the total deaths in a population, but it is fallacious when used for comparison. The third method is, probably, the best method of stating the death-rate from any specified Zymotic disease, but is only applicable to huge masses of population, such as a country or a nation, with a view to approximation to the truth.

In the same way a Death-Rate for Respiratory Diseases and a Death-Rate for Phthisis may be computed in urban communities.

TABLE VIII.

Table showing Death-Rates per 1000 of Population from different Zymotic Diseases, Phthisis, and Respiratory Diseases in England and Wales in different years.

Disease.	1851–60.	1871–80.	1881–90.	1891–95.
Small-pox	·221	·236	·045	·020
Measles	·412	·378	·44	·40
Scarlet Fever	·876	·716	·33	·18
Diphtheria	·109	·121	·16	·25
Whooping-Cough	·503	·512	·45	·39
Fever: Typhus Fever		·06	·015	·004
Fever: Enteric Fever	·908	·32	·20	·17
Fever: Continued Fever		·10	·025	·008
Diarrhœal Diseases	1·080	·935	·67	·65
Zymotic Death-Rate	4·109	3·47	2·36	2·07
Phthisis	2·68	2·12	1·72	1·46
Respiratory Diseases	3·02	3·90	3·73	3·74

In the quinquennium, 1891–95, it may therefore be said that the death-rate per 1000 of population from the principal Zymotic diseases was as follows: Small-pox, ·020 per 1000, or twenty per million; measles, ·40, or four hundred per million; Scarlet fever, ·18, or 180 per million; Diphtheria, ·25, or 250 per million; of Typhus fever, ·004, or four per million; Enteric fever, ·17, or 170 per million; Continued fever, ·008, or 8 per million; Diarrhœal diseases, ·65, or 650 per million.

TABLE IX.—SCOTLAND, 1890–92.

Table showing Age-Distribution of Deaths from Whooping-Cough, Measles, Scarlet Fever, Enteric Fever, and Diphtheria.

Disease.	Under 1	—2	—3	—4	—5	—10	—15	15—	All Ages.
Whooping-cough	403	310	124	65	41	55	1	1	1000
Measles	214	386	167	80	48	87	5	15	1000
Scarlet Fever	75	136	148	136	108	254	74	69	1000
Enteric Fever	4	13	17	20	18	122	135	671	1000
Diphtheria	76	175	144	137	119	249	48	52	1000

Graphic or diagrammatic methods for presenting statistical facts are now largely employed. They possess the advantage over columns of figures which always require careful study, that they enable the observer to comprehend more quickly the facts so portrayed. The following figures represent two of these forms. (Figs. 108, 109.)

Urban and Rural Death-Rates.—Urban death-rates are usually higher than rural death-rates, even after the usual corrections have been made. This is due to a variety of factors, viz.: density of population, artificial conditions of life, occupation, etc.

In rural districts and small villages, any figure between 10 and 16 per 1000 may be reckoned as fair average death-rates; in towns with

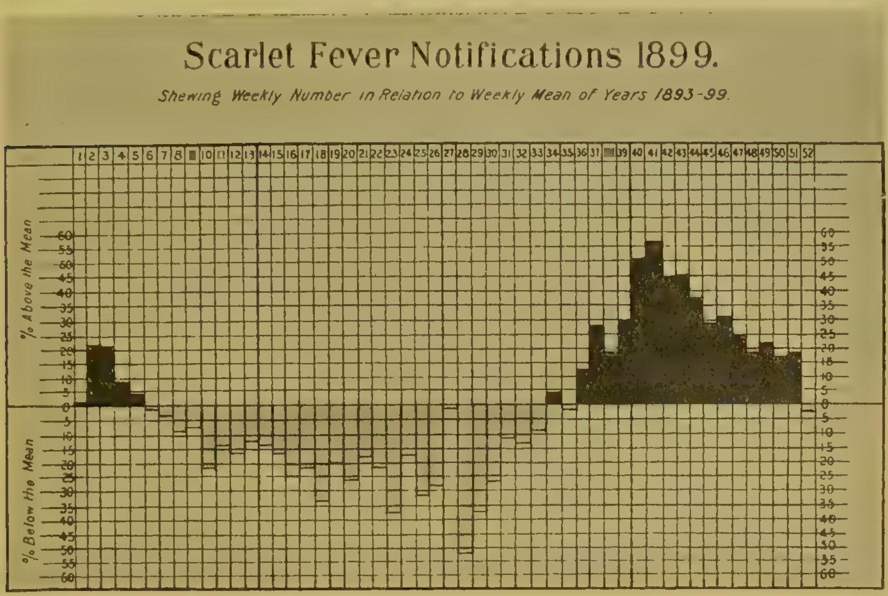


FIG. 108 illustrates one of the graphic methods of presenting statistical facts. The above figure is intended to show the percentage in the Weekly Returns of Scarlet Fever Notifications in Glasgow for 1899 above or below the Weekly Mean for the years 1893–99. A glance at the figure at once shows whether in any given week the percentage of notifications was above or below the mean of the same week during the years above given. The mean for each week of the period 1893–99 is taken as a standard figure, with which the notification returns of each week in 1899 are compared and contrasted. (Report Med. Off. Health of Glasgow for 1899 and 1900.)

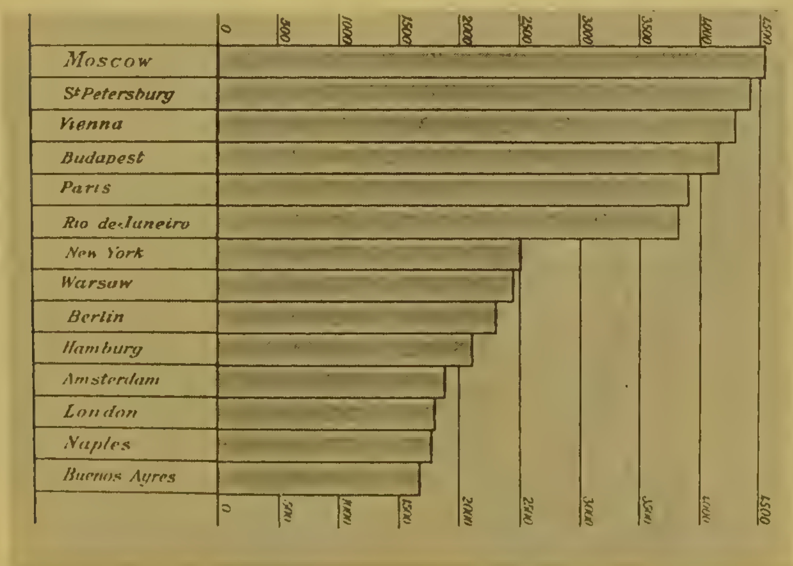


FIG. 109 illustrates as Death-Rates per Million of Population the prevalence of Tuberculosis in the Capitals of several Countries of the World. (City of Edinburgh Report on Tuberculosis, 1900.)

populations varying between 5000 and 20,000, 15 to 18 per 1000; in cities of 30,000 to 100,000, 17 to 20 per 1000; and in large cities of

over 100,000 of population, 18 to 21 per 1000. The death-rates for England and Wales, and for Scotland, have undergone progressive diminution during the last fifty years; for example, while the rate for England and Wales was 23·3 in 1846–50, 22·4 in 1866–70, 20·8 in 1876–80, 18·9 in 1886–90, it further fell to 18·7 in 1891–95. In the large English towns, it has fallen from 24·7 in 1851–60 to 20·2 in 1881–90. In Scotland a like progressive diminution has been recorded in the principal towns, and of the country generally. Of the latter, in 1900 the rate was 19·070 per 1000.

Conditions to be observed in all Statistical Calculations :—

1. Facts, or numerical units, must be exactly comparable. As Parkes puts it, "the dividing character must be so definite as to leave no doubt into which group an unit shall fall; it must be precise enough to prevent the possibility of an unit being in two groups at the same time."

2. The facts, or numerical units, must be arranged into groups, and a constant numerical standard must be adopted to show the relation of the groups to the units. This standard may be per 100, 1000, or a million.

3. The smaller the number of facts from which certain conclusions are inferred [the process being *in*duction not *de*duction], the greater the liability to probable error; and the converse is true. The *probable error* has been well defined as "the amount of departure from the average within which, on one side or other, it is an even chance that the truth exists." In all calculations derived from small numbers, therefore, while they are true of that set of facts, they must not be taken as true of the next series of facts; in other words, variation exists, which variation is the probable error. This will be better illustrated by concrete examples. We speak, for example, of the "average" or "mean" death-rate. For instance, in the decade 1871–80 the mean death-rate was 28·09 per 1000 of the population, and by that is meant that the sum of the death-rates of the years 1871 to 1880 inclusive divided by ten, the number of years, was 28·09; but in that series of figures each was different. *The mean or average, therefore, is obtained by dividing the sum of the facts by the number of them.* This is called the *Arithmetical Mean* or *Average.* The following is a worked-out example—:

TABLE X.

Death-Rates of Glasgow, 1871–80.

Year.		Rate.
1871	=	32·90
1872	=	28·75
1873	=	29·14
1874	=	31·43
1875	=	29·28
1876	=	26·17
1877	=	26·12
1878	=	26·82
1879	=	24·21
1880	=	26·08
	Total	280·90

∴ 280·90÷10 = 28·09 = Arithmetical Mean Death-Rate.

It will be observed, however, that in that series of figures some of the figures are above, and some below the mean, or average. Therefore, it would not be correct to say that 28·09 was the true death-rate of the period, but only approximately true. The relation of this arithmetical mean to the series of facts from which it is obtained is such that the differences of the mean of the numbers greater than the mean from which the mean of the whole series is subtracted, and of the mean of the numbers less than the mean subtracted from the mean of the whole series, exactly neutralise or are equal to one another. Thus:—

Death-Rates greater than Mean of whole Series—28·09.

1871	=	32·90				
1872	=	28·75				
1873	=	29·14				
1874	=	31·43				
1875	=	29·28	=	151·50÷5	=	30·30

Death-Rates less than Mean of whole Series.

1876	=	26·17				
1877	=	26·12				
1878	=	26·82				
1879	=	24·21				
1880	=	26·08	=	129·40÷5	=	25·88

30·30 − 28·09 = 2·21 = error in excess.
28·09 − 25·88 = 2·21 = error in deficiency.
2·21 + 2·21 = 4·42
4·42 ÷ 2 = 2·21 = mean error.
2·21 × 0·6745 = 1·49 = probable error.

Therefore the death-rate might in the next series of death-rates be either 28·09 + 1·49 = 29·58; or 28·09 − 1·49 = 26·60. To find the mean error: (1) find the mean of the series of observations; (2) find the mean of the observations above the mean of the whole, and subtract the mean from it, which will be the mean error in excess; (3) find the mean of the observations below the mean of the whole, and subtract it from the mean, which will be the mean error in deficiency; (4) add the two quantities, and take the half; and the answer will be the mean error; the *probable* error is 0·6745 or roughly $\frac{2}{3}$ of the mean error.

Another method of estimating the probable error is Radicke's "Method of Successive Means."[1] The method may be demonstrated from the same figures.

First Mean		= 32·90
Second „	= 32·90 + 28·75 ÷ 2	= 30·825
Third „	= 32·90 + 28·75 + 29·14 ÷ 3	= 30·263
Fourth „	= 32·90 + 28·75 + 29·14 + 31·43 + 29·28 ÷ 5	= 30·300
Fifth „	= from six data	÷ 6 = 29·611
Sixth „	= „ seven „	÷ 7 = 29·113
Seventh „	= „ eight „	÷ 8 = 28·826
Eighth Mean	= „ nine „	÷ 9 = 28·313
Ninth Mean	= „ ten „	÷ 10 = 28·09

[1] *New Sydenham Soc.*, vol. xi. p. 1861, "On the Importance and Value of Arithmetical Means."

From the foregoing set of means it will be seen that it is only in the last three that the figure 28 is common, and that they approach the arithmetical mean or average.

Radicke also advises, in order that the truth may be still more nearly approached, the employment of the Quadratic Mean, which is the square root of the arithmetical mean of the squares of the given numbers.

In addition to the arithmetical and successive means, there are the geometric, harmonic, and quadratic means, which, however, are hardly ever used in practice for statistical calculations. The reader is referred to the monograph by Radicke for fuller information (*loc. cit.*). The bases of the methods by which these means may be arrived at may, however, be set down.

Suppose it is required to ascertain the mean of the following four numbers, 6, 8, 9, 3 by these different means. Then, the *arithmetical mean* is obtained by dividing the sum of the observations by the number of them, thus:—

$$\frac{6+8+9+3}{4}=6{\cdot}5.$$

The method of *successive means* is obtained by taking the mean of the first two numbers, then of the first three, then of the first four, and so on until the series of observations is exhausted. The accuracy or inaccuracy of the mean is exhibited by the concurrence or non-concurrence of the figures of the different means obtained, results which depend upon the largeness or smallness of the number of observations. In our example there can be no pretence to accuracy.

$$\frac{6+8}{2}=7$$

$$\frac{6+8+9}{3}=7{\cdot}6$$

$$\frac{6+8+9+3}{\quad}=6{\cdot}5$$

The *geometric mean* is the product of the figures of the observations multiplied together into the root of the number of observations, thus:—

$$\sqrt[4]{6\times8\times9\times3}=\sqrt[4]{1296}=6.$$

The *harmonic mean* is the "reciprocal value of the arithmetical mean of the reciprocal values of the given numbers." The reciprocal value of any number is that number used as the divisor of unity; thus the reciprocal value of $6=\frac{1}{6}$, of $9=\frac{1}{9}$, of $8=\frac{1}{8}$, and so on. In the above case, it works out thus:—

$$\frac{\frac{1}{6}+\frac{1}{8}+\frac{1}{9}+\frac{1}{3}}{4}=\frac{\frac{954}{1296}}{4}=\frac{238\frac{1}{2}}{1296}=\frac{1296}{238\frac{1}{2}}=5{\cdot}4339.$$

The *quadratic mean* is the square root of the arithmetic mean of the squares of the given numbers, thus:—

$$\frac{\sqrt{6^2+8^2+9^2+3^2}}{4}=\sqrt{\frac{190}{4}}=\sqrt{47{\cdot}5}=6{\cdot}89.$$

It will be observed that the means of the figures above given are different from each other. They are respectively:—

Arithmetic mean = 6·5
Method of successive means = a figure which is derived from too small a number of observations to pretend to any value to accuracy.
The geometric mean = 6.
The harmonic mean = 5·4439.
The quadratic mean = 6·89.

According to Radicke the quadratic always exceeds the arithmetic mean, depending upon the greater inequality of the numbers: the more equal the numbers the greater the coincidence.

The arithmetical mean may be used in different sets of circumstances, viz.:—

First, as the expression of a pure average, where it is applied to numbers which are exact and definite. It may be applied to ages of a body of individuals,

or to any other definite sets of ascertained facts. Ten persons, for example, are aged respectively, 2, 6, 8, 10, 20, 60, 65, 80, 84, 91. The average age of the group will therefore be 42·6 years, on the supposition that the surplus of years of the seniors could be transferred to the juniors. In another group of ten, however, the average works out as 36. All that may legitimately be inferred from these facts is that the aggregate of ages of these two groups has the relation of 42·6 and 36.

Second, as the expression of the probable value of a definite fixed quantity. This method may be applied to a series of measurements of an object, a series of chemical analyses of a given fluid, or such like problems in which errors originating in the observer are likely to arise.

Third, as the expression of the probable value of a variable quantity estimated under mean conditions. Most statistical calculations are of this nature, and being liable to probable error from different factors must be corrected or subjected to corrections against probable error.

The best method of arriving at the probable error in cases where a series of facts is divided into two sub-component groups is by *Poisson's Rule* or *Formula*, which may be thus expressed :—

Let μ be the total cases in the series;
" m be the number in one sub-component group;
" n be the number in the other sub-component group.

The proportion of each group to the whole series will be, respectively, $\frac{m}{\mu}$ and $\frac{n}{\mu}$; but these proportions will vary within certain limits in succeeding instances, and the extent of the variation will be within the proportions represented by the following mathematical expressions :—

$$\frac{m}{\mu} + \sqrt[2]{\frac{2.\ m.\ n}{\mu_3}};\ \text{and}$$
$$\frac{m}{\mu} - \sqrt[2]{\frac{2.\ m.\ n}{\mu_3}}.$$

Obviously, the larger the value of μ the less will be the value of $\sqrt{\frac{2.\ m.\ n}{\mu_3}}$, and consequently the less will be the limits of error in the simple proportion of $\frac{m}{\mu}$; and the converse is true.

Gavarret,[1] quoted by Parkes, takes an example from Louis' work on Typhoid Fever, in which Louis tries to determine the effect of remedies by adducing the number of recoveries and deaths in a series of cases of that disease. The series comprised 140 cases, with 52 deaths and 88 recoveries, and the question arose, What is the percentage mortality, and how near is it to the true proportion? The percentage mortality in that series was 37·143. How near is this percentage to the truth?

The probable error is worked as follows :—

Let $\mu = 140 =$ the total number of cases.
$m = 88 =$ the number of recoveries.
$n = 52 =$ the number of deaths.

$$\text{then } \sqrt[2]{\frac{2 \times 52 \times 88}{140_3}} = \sqrt[2]{\frac{9152}{2744000}} = \sqrt[2]{\cdot 00331} = \cdot 05771 \times 2 = \cdot 115420$$

to unity; or 11,550 in 100,000 cases.

The mortality being 37·143 per cent. in that series, or 37,143 deaths in 100,000 cases, by the first part of the formula it may either be 37·143 + 11·550 = 48·693 per cent., or 48,693 in the next 100,000 cases, or by the second part of the

[1] *Statistique Médicale*, 1840, p. 284.

formula, 37·143 − 11,550 = 25·593 per cent., or 25,593 in the next 100,000 cases; in other words, in another series of the same number—140—the percentage mortality will range from nearly 49 per cent. to nearly 26 per cent. The range of probable error, therefore, is very great from such a small number of observations, and the percentage mortality of this series of little or no value in forecasting the mortality of the next. Newsholme demonstrates[1] by this formula the statement that the smaller the number of data from which a calculation is made the greater the probable error. He puts it thus: If out of ten cases of cholera seven recover, how near is this to the true average rate of recovery? What will be the possible variation in 100,000 cases on this basis?

$$\sqrt[2]{\frac{2 \times 7 \times 3}{10_3}} = \sqrt[2]{\frac{42}{1000}} = \cdot 40980 \text{ to unity, or } 40{,}980 \text{ to } 100{,}000 \text{ cases,}$$

that is, $70 + 40 \cdot 98 = 110 \cdot 98$ per cent., or 110·98 in 100,000 cases, which is absurd; or $70 - 40 \cdot 98 = 29 \cdot 02$ per cent., or 29·020 in 100,000 cases.

If the number of cases be raised to 100, the other ratios remaining the same, the error falls to as ·13 is to unity; in other words, in 100,000 cases, the recovery rate may be either 83,000, or 57,000. Raising the number of cases to 1000, other things equal, the error further falls to as ·04 is to unity; so that in 100,000 cases, the number of recoveries may be either 74,000 or 66,000. When we come to a million cases, the error sinks into insignificance, being only as ·0013 is to unity; for in 100,000 cases the number of recoveries may be either 70,130 or 69,870, which is practically the truth.

It ought to be remembered that the percentage expression of a result from a series of accurately observed data is an accurate expression of the truth with respect to that series only, and is only approximately near the truth as an expression of the result in the next or other series of cases; therefore, for purposes of comparison, or as a forecast, it is only approximately correct. Statistical fallacies mostly arise from trying to compare incomparable things, and from imperfect constitution of groups. As an example of the former may be taken the common fact of instituting comparisons of the healthiness of two districts from their death-rates. While, although every care may be exercised on all points to make the comparison as equal as it can be made and the fallacy may not be serious, it nevertheless still exists. Another fallacy is involved in the comparison of the number of deaths from any given disease in two different years of a population, unless due allowance is made for the altered incidence of population in the interval. Further, fallacy is often involved in the attempt to arrive at the mean death-rate of a county, for example, by taking the mean of the separate rates returned for different districts. Say, for example, that the death-rate of District A, with a population of 15,000, is 24 per 1000; that of District B, with a population of 18,000, 22 per 1000; and that of District C, with a population of 22,000, 26 per 1000; it would be incorrect to conclude that the average death-rate was $24 + 22 + 26 \div 3 = 24$ per 1000. The problem of ascertaining the true average is worked out as follows:—

Population of A	=	15,000
Population of B	=	18,000
Population of C	=	22,000
Total population	=	55,000

[1] *Op. cit.* 1st ed., p. 295.

$$\left(\frac{15{,}000}{55{,}000}\times 24\right)+\left(\frac{18{,}000}{55{,}000}\times 22\right)+\left(\frac{22{,}000}{55{,}000}\times 26\right)=\left(\frac{15}{55}\times 24\right)+\left(\frac{18}{55}\times 22\right)+\left(\frac{22}{25}\times 26\right)$$
$$=\frac{360+396+572}{55}=24{\cdot}8=\text{Average Death-Rate.}$$

If the death-rates for Districts A, B, C had, however, been 24, 12, and 26 respectively, the other factors remaining the same, the death-rate by the former method would have been 20·67, whereas, properly calculated, it would have worked out as 20·48. It will easily be seen, where the figures in the problem diverge more widely, how much greater the error is likely to be.

There are certain terms used in statistics the meaning of which ought to be clearly comprehended.

Mean age at death is the average age at which death occurs in a mixed population, and is the figure obtained by dividing the sum of the ages of persons who die in the year by the number of deaths.

$$\frac{\text{Sum of Ages at Death}}{\text{Number of Deaths}}=\text{Mean Age at Death.}$$

Mean Duration of Life, or *Expectation of Life at Birth in a stationary population* mean exactly the same thing as the *mean age at death*; but in a progressive population they differ considerably. In England and Wales, for example, in 1881–90, the mean duration of life for males was 43·66 years, whereas the mean age at death was 29 years. In progressive populations, therefore, the mean duration of life is found from Life-Tables, which represent the life progress of a generation of a million from birth to death. In Farr's Life-Table No. 3, which was based upon the Census returns of 1841 and 1851 and upon six million odd deaths registered from 1838–1854 inclusive, the mean age at death is 40·9 years, which was equivalent to the mean after-life-time, and the population in the Table became reduced to one-half in 45 years, which, therefore, was the *probable life-time*. In the absence of Life-Tables, which, however, are the most accurate methods of ascertaining such statistical data as the foregoing, *Willich's formula* for ages between 25 and 75 serves the purpose approximately, viz.:—

$$x=\frac{2}{3}(80-a)\text{; where } x=\text{expectation of life;}$$
$$a=\text{age of individual.}$$

Thus by this *formula* the expectation of life of a person aged 30 would be:—

$$x=\frac{2}{3}(80-30)=33{\cdot}3\text{ years.}$$

Farr's formula may also be used, where the birth- and death-rates of a community over a long period are known, viz.:—

$$\left(\frac{2}{3}\times\frac{1}{d}\right)+\left(\frac{1}{3}\times\frac{1}{b}\right)$$

where d = death-rate, and b = birth-rate.

If the average death-rate of a community in 1891–92 was 20 per 1000, or ·02 per unit, and the birth-rate 34 per 1000, or ·34 per unit, what would be the expectation of life?

Reduced to terms the equation is as follows :—

$$\left(\frac{2}{3}\times\frac{1}{\cdot 02}\right)+\left(\frac{1}{3}\times\frac{1}{\cdot 034}\right) = 33\cdot\dot{3}+9\cdot 804 = 43\cdot 104 \text{ years.}$$

The term *probable duration of life*, sometimes called the *equation of life*, is the age at which a million children born will be reduced one-half, which by Farr's Table No. 3 is 44·43 years for males, and 46·42 years for females; and by Tatham's Table, 1881–1890, for males 43·66 years, and for females 47·18 years. In Chalmers'[1] Life-Table for Glasgow, 1881–1890, the expectation of life at birth of a male is 35·18, in Manchester 34·71, and Brighton 43·59 years.

STATISTICAL TESTS BY WHICH THE HEALTH CONDITIONS OF A COMMUNITY MAY BE GAUGED.

The following are probably the best tests, viz.:—

First.—The Corrected Death-Rate, where the population is fairly large and not liable to sudden fluctuations one way or other, and in the absence of unusual epidemics;

Second.—The Rate of Infantile Mortality, which is an index of the conditions of life of children, or of occupations of the mothers;

Third.—The Zymotic Death-Rate. While this is liable to fluctuations due to causes somewhat outside the control of a sanitary department, a high rate may be taken as indicative of insanitary conditions;

Fourth.—The Respiratory Diseases Death-Rate indicates either unhealthy climatic conditions, smoky irritating atmosphere, or unhealthy occupations or conditions of home life, or some of these combined;

Fifth.—The Phthisis Death-Rate is also indicative of the same general conditions.

[1] "A New Life-Table for Glasgow," 1894.

CHAPTER III.

METEOROLOGY.

A WELL-ORDERED annual report cannot be considered complete without furnishing information respecting certain meteorological data. Of these, the following are of the first importance, viz. :—

I. Temperature; II. Atmospheric Humidity; III. Rainfall; IV. Barometric Pressure. To each of these some brief attention must be given.

I. *Temperature.*—A record of temperature ought to be taken at least night and morning at different stations, as well as a record of the mean and extreme temperatures. Temperature may be considered in relation to its changes in *space* and in *time.* The changes or differences of temperature in *space* bring in the whole question of climatology, while those in *time* deal only with periodic variations, either hourly, daily, seasonally, or annually. It is with this last feature that the health officer has chiefly to deal. Extremes of temperature are simply indicated by the highest and lowest readings of the thermometer which may occur in any given place during any given period; thus there are diurnal as well as seasonal extremes. The readings of such temperatures are recorded by thermometers in the shade as well as by those in the open. Of the former there is a maximum and a minimum instrument, and in use these are protected from radiation by a louvred screen, their height being four feet from the ground-level.

Maximum Thermometer.—The maximum instrument consists of a mercurial column the index of which is formed by a smaller column of mercury separated from the main column by a minute bubble of air, by the expansion of which the index is pushed forward to its furthest point, but which does not recede when the air contracts; hence the end of the index furthest from the bulb of the instrument indicates the highest temperature recorded during the day of observation. When setting the instrument for use it must be swung briskly with the bulb downwards, so as to cause the mercurial index-column to recede to a low reading. When set, it should be placed in a horizontal position.

Minimum Thermometer.—There are two kinds in use, that of Casella which is filled with mercury, and that of Rutherford, with spirit. The former, because of the difficulty experienced in its manipulation, is seldom used. In the latter the index is immersed in spirit. When used, the index is permitted to run down to the end of the column by simply sloping the instrument with the bulb uppermost; it is then placed in its horizontal position. Should the temperature rise, the spirit simply flows past the index leaving it

undisturbed, but should it fall, the index recedes with the spirit, and so records the lowest reading within the time for which it has been set. This instrument is liable to the serious objection that a portion of the spirit may evaporate from the bulb and condense in the upper part of the column of the instrument. There is, however, one instrument which records at the same time both the maximum and the minimum temperature. It is a spirit thermometer, the tube of which is bent on itself—parallel-wise—with a bulb at each end, one bulb being larger than the other. Each bulb is filled with spirit, but the smaller one contains also a bubble of air. The bend of the bulb is filled with mercury, and the registration is accomplished by two indices which consist of steel pins seated in glass tubes, having hairs attached to the tubes to keep them in any position to which they may have been pushed by the mercury column, or by the steel magnet employed to set them. To set the instrument, the steel indices by means of the small magnet are brought down to rest on the top of the mercurial column. When the temperature rises, expansion takes place in the spirit in the larger bulb and pushes the mercury and index before it, which latter remains at the highest or furthest point attained. When the temperature falls, the spirit contracts, and the pressure of the bubble of air in the smaller bulb propels the mercurial column back and so moves the minimum index to its lowest reading. This instrument is kept in a vertical position.

The thermometers used in the open are also a *maximum* and *minimum;* the former indicating the highest temperature in the sun, the latter, the lowest. The former has a blackened bulb *in vacuo* and is placed in position on forked sticks about four feet above the ground. The minimum instrument possesses a clear bulb.

The term "mean temperature" is one which is frequently employed in connection with health resorts, and in meteorological reports. If hourly thermometric observations are made, the mean is approximately the sum of the twenty-four readings divided by that figure. But the term is also used with reference to months, a year, or a series of years. While, however, the mean daily temperature may be approximately determined as described, the result is not actually correct. A formula has been constructed by Kaentz, modified by Lloyd, to arrive at the correct mean, viz. :—

Min. reading + (Max. reading − Min. reading) × co-eff. a = Mean Temperature.

For example : Max. temp. on a given date = 54·2° F.,
Min. ,, ,, same ,, = 41·4° F.,

$$\therefore\ 41{\cdot}4 + \{54{\cdot}2 - 41{\cdot}4 \times {\cdot}41\} =$$
$$41{\cdot}4 + \{12{\cdot}8 \times {\cdot}41\} =$$
$$41{\cdot}4 + 5{\cdot}25 = 46{\cdot}65^\circ = \text{Mean Temperature.}$$

The mean annual temperature of any given place is practically of little value. For example, the mean annual temperature of Dublin is 49·3° F., and that of New Haven in Connecticut, 49·2° F., but the climates of these two places are very different. In January, the temperature of Dublin is 40·6° F., while in the same month that of New Haven is 26·6° F.; in July, that of the former place is 59·7° F., while that of the latter is 71·6° F. The difference, therefore, between

the coldest and the hottest months is for Dublin only 19·1° F., and for New Haven 45° F. Again, the mean annual temperature of St. Louis is 53·96° F., and of Algiers, 55·76° F., but the summer temperature of the former place is 74·84° F., and the winter temperature is 32·9° F., while the temperatures of Algiers for these respective seasons are 73·94° F., and 53·96° F. The mean annual temperature of places, therefore, of itself gives no information as to the annual range of temperature, except where the places are situated in the same kind of climate, insular or continental.

Of great importance is the *Amount of Sunshine.* This is recorded by means of Campbell's or Jordan's apparatus. In the former apparatus a glass sphere focusses the pencil of rays upon a sheet of paper placed at the necessary distance on a convex surface. The amount and intensity of the sun's rays are recorded by the amount and degree of scorching of the paper. In the latter apparatus the recorder is a small, flat, circular box in which is a slit. Within the box is sensitised paper, as used in photography. The sunshine, passing through the slit, records itself upon the paper, which appears on "developing" the paper.

II. *Atmospheric Humidity.*—There is always present in the atmosphere a certain amount of moisture in the form of gas, or aqueous vapour as it is termed, which is obtained by evaporation. Evaporation is diminished or increased by the lowering or raising of the temperature, and is limited by any confinement of the space into which the aqueous vapour is passed. The presence of aqueous vapour over the surface of a vessel of water for example, hinders evaporation; that is to say, the greater or lesser quantity of aqueous vapour already contained in the atmosphere, the greater or smaller will be the amount of evaporation, and the nearer the point of saturation the atmosphere is the less will be the evaporation. During evaporation of water to the gaseous state heat is being constantly communicated to the vapour passing off; when this heat is withdrawn from the vapour, it condenses back into the condition of water. The chief action of watery vapour in the atmosphere is to modify the action of the sun's heat upon the earth, and also the radiation of heat from the earth. The "*point of saturation*" of air is that point at which the air at any given temperature cannot hold any more aqueous vapour in the gaseous form. As is the temperature of the air at any given time, so is the total possible amount of vapour which it can sustain. Most usually, however, the air only holds some proportion of this total amount. Most comfort is experienced when the atmosphere contains 70 to 80 per cent. of the possible total amount it can hold at that temperature. When the temperature of the atmosphere at saturation-point falls, the air ceases to be able to sustain the quantity of vapour it formerly held, and part of it is condensed in the form of water, or dew, hence this point is called the *dew-point.* The temperature of the dew-point will, therefore, vary with the temperature of the atmosphere. The term "*absolute*" *humidity* is intended to express the actual amount of watery vapour which the atmosphere can hold at a given temperature, that is, while in a state of saturation; the term "*relative*" *humidity*, that proportion of the

total possible amount of aqueous vapour which the atmosphere at a given temperature actually holds. The latter is usually expressed as a percentage quantity or fraction of saturation. The term "*tension of aqueous vapour*" means the measure of the elastic force exercised by the aqueous vapour in the atmosphere, expressed in terms of an inch of mercury.

Hygrometry is the mode of determining the amount of aqueous vapour, or moisture, present in the atmosphere, the instruments used being called hygrometers. From the results recorded by these, relative humidity, dew-point, and tension of aqueous vapour are determined. Hygrometers are of two kinds, viz.: direct, and indirect. The instruments of Daniell, Reynault, and Dine belong to the first class, while the pyschrometer or wet-and-dry bulb thermometer, and Saussure's or the hair hygrometer belong to the second.

Direct Hygrometers.—In the three first-named instruments, the temperature at which dew deposits is brought about by cooling; in Daniell's instrument, by the cooling produced by evaporation of ether from an outside muslin coating which covers the clear bulb; in Regnault's by the passage of a current of air which is aspirated through the ether, and in Dine's by the use of very cold water, or iced water. The points to be noticed are these, viz.:—

1. The temperature at which dew deposits on the opaque bulb, or glass-plate;
2. The temperature at which it disappears;
3. If the mean of these two observations be taken, that is the "dew-point" temperature;
4. Take the "tension" corresponding to the temperature of dew-point (obtained from a table of tensions), divide it by the tension corresponding to the temperature of the air at the time, and the result will be the hygrometric state of the atmosphere in terms of relative humidity.

The objections to Daniell's instrument are: (*a*) liability to incorrect reading of immersed thermometer; (*b*) compulsory proximity of observer affecting temperature recorded by attached thermometer. Regnault's instrument is very efficient. Dine's is simpler than the other, and is also very efficient.

Indirect Hygrometers.—The wet-and-dry bulb thermometer is the instrument now most commonly used. It consists of two thermometers, the bulb of one of which is coated with muslin to which is attached a small bundle of wick threads, both of which are kept moistened by capillary action, the ends of the threads being caused to dip into a small vessel of water. The principle of the instrument is, that so long as the atmosphere is not saturated evaporation will take place from a damp surface, and the amount of evaporation will be indicated by the lower reading of the wet bulb instrument. If the air be saturated no evaporation will take place, and accordingly the readings of both instruments will be identical.

In the absence of a table of tensions of aqueous vapour the tension may be found by Apjohn's formula from the readings of the above instrument.

Let f = tension of vapour at dew-point temperature, which is to be found;
f' = tension of vapour at temp. of evaporation as recorded by wet-bulb instrument;
a = specific heat of air;
c = latent heat of aqueous vapour;
$(t-t')$, or d = difference in temperature-readings between dry and wet-bulb instruments;
p = pressure indicated by barometer, in inches:—

$$\text{Then } f=f' - \frac{48a\,(t-t')}{c} \times \frac{p-f'}{30};$$

or, with the co-efficient:—

$$f=f' - \cdot 01147\,(t-t') \times \frac{p-f'}{30}.$$

The Greenwich modification of the formula is as follows, where h = height of barometer:—

$$f=f' - \frac{d}{88} \times \frac{h}{30} = \text{for temperatures above } 32^\circ \text{ F.},$$

$$\text{or } f=f' - \frac{d}{96} \times \frac{h}{30} = \text{ ,, ,, below } 32^\circ \text{ F.}$$

Example.—Find the vapour tension where the temp. of the dry bulb is 65° F., that of the wet bulb 61° F., the tension of the air at 65° F., being ·617 inches of mercury, and of the wet bulb at 61° F., ·537 inches?

$$f=f' - \frac{d}{88}$$

$$f=\cdot 537 - \frac{65-61}{88};$$

$$f=\cdot 537 - \frac{4}{88}$$

$$f=\cdot 537 - \cdot 04\dot{5}$$

$$f=\cdot 49145 = \text{tension of vapour at dew-point.}$$

Relative humidity
·617 = tension of vapour of air at 65° F.,
∴ ·49145 ÷ ·617 = 79 per cent.

The dew-point may also be calculated by the aid of Glaisher's tables, thus. From the temp. of the dry-bulb instrument subtract the reading of the wet-bulb; multiply the difference by the factor corresponding to the dry-bulb temperature, and subtract the product from the dry-bulb temperature: the result is dew-point.

Example.— The dry-bulb temperature = 53° F.,
The wet-bulb ,, = 49° F.,
Then 53 − 49 × 2·00 (factor corresponding to 53° F.) = 8.
∴ 53 − 8 = 45° F. = the dew-point temperature.

Saussure's hygrometer is based on the fact that a hair becomes longer or shorter as the air is damp or dry. In this instrument, a human hair, which has never been oiled or handled roughly, is used. One end of the hair is fixed in the instrument, the other being kept stretched by a light weight attached to it, which weight is attached to a connecting cord pressing round the sheaf of a block, to which is fixed an arm or index moving in a graduated arc. As the hair shortens or lengthens, the index moves and records the difference in vapour present in the atmosphere.

III. *The Rainfall.*—The amount of rainfall is of importance in relation to the maintenance of water-supplies. In the term rainfall is included all moisture which falls in particulate drops, either as a liquid or solid, as rain, snow, or hail. The amount is estimated by

rain-gauges, of which Howard's, Glaisher's, the Snowdon, and others are the principal. Howard's instrument is the simplest, and consists of (*a*) a funnel; (*b*) a receiver; and (*c*) a graduated measuring glass; Glaisher's differs only in that the receiver is made of copper, and the delivery-tube of the funnel is bent in the form of a curve, in order to prevent evaporation. The Snowdon gauge consists of a funnel with straight stem enclosed in a cylinder—for better snow collection—having a diameter of eight inches. The position of the gauge is of importance, in order that the true fall be estimated. It must be put at a height—from brim to ground-level—of not less than one foot; it must be firmly fixed, and its brim perfectly level; evaporation should be prevented so far as possible; and it must be placed in a perfectly open position, so that the rainfall will not be influenced by sheltering objects as trees, walls, shrubs, etc. The amount of water in the receiver should be measured at the same hour—preferably 9 A.M.—and the result expressed in inches and decimals of an inch. Snow and hail should be melted first before measurement. The factors to be known in the estimation are: (1) the area of receiving-surface of the gauge, which being circular is the square of the diameter + ·7854; and (2) amount of water in the receiver, measured in a graduated glass.

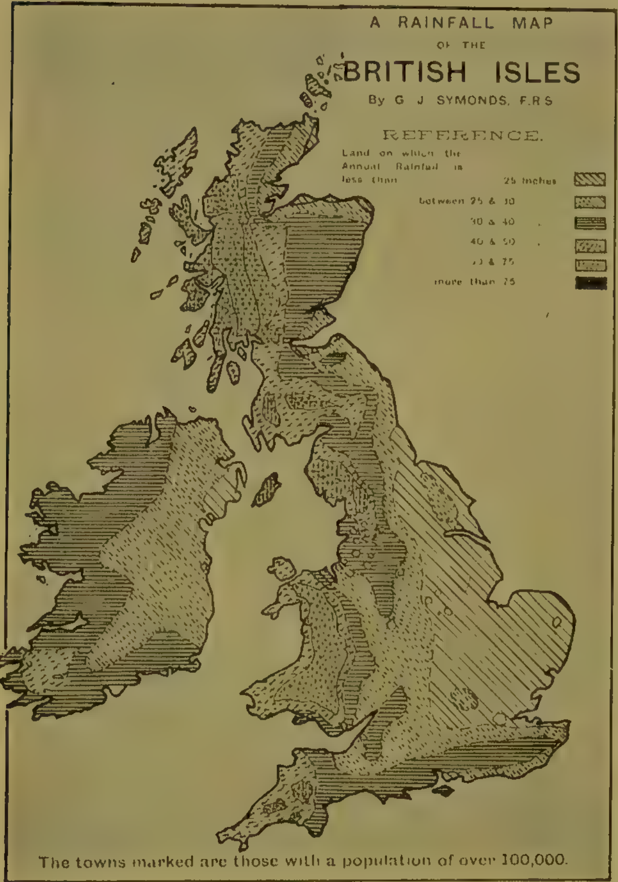


FIG. 110.—Map of Rainfall of British Isles.

The amount of rainfall has a certain close relation to the prevailing winds. In these islands, the greatest rainfall obtains with the westerly and south-westerly winds, which crossing the Atlantic charged with moisture, tend to deposit it as rain on the western sea-board. For this reason, highest rainfalls are recorded on the west and south-west, and the lowest on the east coasts. The presence of elevated land affects the incidence of the rainfall. When a current of air charged with moisture comes in contact with mountain or hill-tops, condensation occurs, and the rain falls. It is by reason of the more mountainous character of the western sea-board, as one cause, that higher rainfalls prevail there than upon the eastern shores. The

average annual rainfall of the western coast of Scotland or Ireland amounts to 60 to 80 inches, while on the eastern it only reaches from 20 to 35 inches. We have computed the total rainfall in the British Islands, with a total acreage of 76,650,219, and an average fall of thirty inches per annum, to amount to 232,000,000,000 tons of water; but a very large proportion of this finds its way back to the sea by the rivers, and to the atmosphere by surface evaporation. Taken as a whole, it is calculated that one-third or one-quarter of the total rainfall flows off the surface upon which it falls, and that the remainder is partly absorbed into the soil, and partly given back to the atmosphere by evaporation.

IV. *Atmospheric Pressure.*—Gaseous bodies have certain common properties with liquids. They possess weight, and they transmit pressures equally in every direction. A litre of air at 32° F., at a pressure of one atmosphere weighs 1·293 grammes; water in like conditions weighs 1000 grammes; therefore, $1000 \div 1{\cdot}293 = 773$; in other words, air is 773 times lighter than water. The atmosphere is a gaseous mantle which envelops the earth, and has been estimated to attain a height above the earth of from 50 to 212 miles. It exerts, at the same level, pressure equally and in every direction upon every object, animate and inanimate. But on account of the compressibility of gaseous bodies, the lower levels of a high column are denser than the higher; but even in these, the pressure is equal and constant at the same time and at the same level. Whenever inequality of pressure occurs at any two or more adjacent points of the atmosphere movement of air is at once set up. Torricelli's experiment proved this law: that the pressure of the atmosphere at the earth's surface on the sea-level is equal to the weight of a column of mercury of a height of thirty inches. If the same experiment be performed with water,

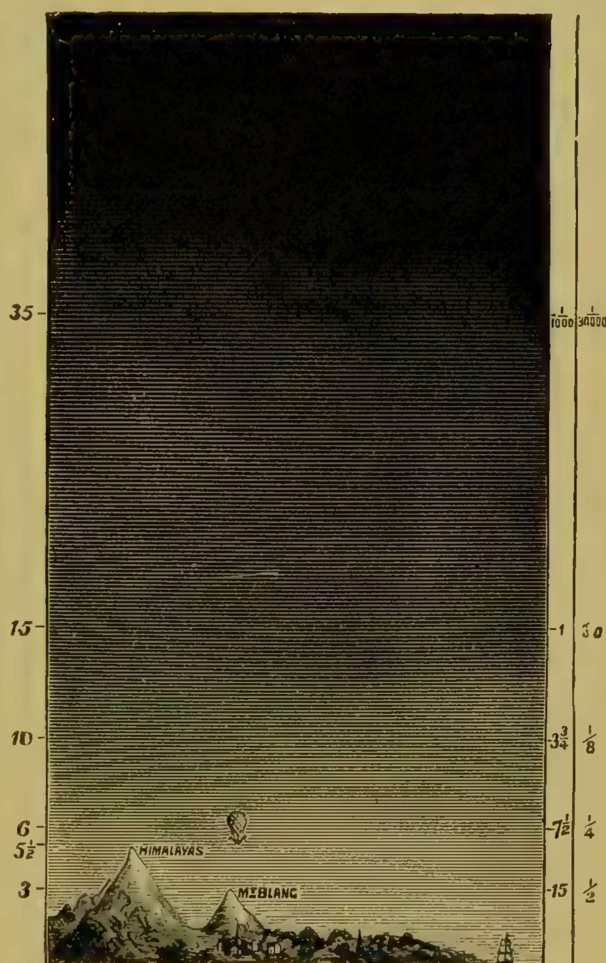


FIG. 111.—The figures on the right of the diagram show the readings of the barometer in inches corresponding to those on the left of height in miles.

the column would reach thirty-four feet in height, since the density of mercury is 13·59 times greater than that of water; and if with glycerine, the column would be 27 feet high, since the density of glycerine is 1·26 times greater than water. Variations of pressure are much more easily read in a glycerine barometer, because of the greater range of the movement of that fluid; for example, the pressure which would raise or depress the mercurial column one inch would raise or lower the other 10·7 inches. Such an instrument is in use in the *Times* office, London.

The pressure of the atmosphere in this country is generally calculated as upon a square inch of surface; that is to say, it is the weight of a column of mercury whose base is a square inch and whose height is 30 inches; in other words, the weight of 30 inches of mercury. Accurately weighed, this amounts to 14·73 pounds, usually reckoned as 15 pounds. Owing to the laws of gases, the higher levels of the atmosphere sustain a less pressure than the lower, consequently the column of mercury becomes lower in height as ascent is made into the higher reaches. Hence at an altitude of 12,000 feet above sea-level the pressure is only one-half of that at sea-level. In Great Britain the mercury falls one-tenth of an inch for every ninety feet ascended. From the Torricellian tube was constructed the instrument to which Boyle gave the name of barometer. British barometers are graduated in divisions of $\frac{5}{100}$ths, tenths, half inch, and one inch divisions; the last two divisional lines being bolder than the rest.

Reading the Barometer.—For the more accurate observation of the height of the mercury, and since the exact level may be between the hundredths of an inch, most modern instruments have attached to them a graduated sliding arm which is called the "vernier." It is so graduated that twenty-five of its divisions are equal to twenty-four of the main scale, hence each division of it is only $\frac{24}{25}$ of the length of the division of the main scale. The divisions on the barometer being $\frac{1}{20}$ of an inch, the vernier will, therefore, enable a reading to be made of $\frac{1}{25}$ of $\frac{1}{20}$ or $\frac{1}{500}$ of an inch. To use the vernier, its lowest mark is accurately placed on a line level with the top of the mercury. This adjustment may or may not be exactly level with a line on the main scale; if level, the vernier is not needed, as the reading from the main scale will be accurate and sufficient. If not, however, the eye should be run up the line of junction of the vernier and main scales until a point is reached where a line of the vernier is exactly level with a line of the main scale. Suppose, for example, that the mercury stands above 29·65 but below 29·70, and that the point at which the two lines of vernier and main scale correspond is at sixteen divisions of the vernier scale counting from below upwards, then the reading of the instrument will be as follows, viz.: $29{\cdot}65 + (16 \times {\cdot}002) = 29{\cdot}682$ inches. If greater accuracy even than this be desired, the cathetometer, which is employed in the highest scientific work, may be used.

The *Cathetometer* is an instrument which consists practically of a telescope set in levelling screws, with an adjoining spirit-level, and has a vertical scale usually divided into half millimetres. In the telescope part, and in the focus of the eye-piece, are set two very fine lines. By means of adjusting apparatus, the telescope is moved over the scale so that the exact level of the mercury in the barometer, as ascertained by the lines, may be read. Each mercurial barometer has an attached mercurial thermometer, for noting the temperature at the time of the observation.

Mercurial barometers are of different kinds, viz. :—

1. The Standard, Kew, or Fortin's barometer.
2. The Siphon barometer.
3. The Wheel barometer.
4. Adie's barometer.

1. In the Standard or Fortin instrument, the cistern is formed of a tube of boxwood surmounted by a glass tube and closed below by a piece of leather, which can be raised or lowered by a screw. The starting-point of the scale is formed by a pin of ivory which is so adjusted by the screw operating on the leather bottom of the cistern that its point just touches the level of the mercury in the cistern. The only possible errors in this instrument are (*a*) from capillary depression of mercury in the tube, and (*b*) from the temperature or readings of the thermometer. Adie's instrument, known also as the Kew or Marine barometer, is a modification of the foregoing instrument, and like it only requires one reading. The scale is marked on the instrument, but instead of the inches being marked uniformly true, they are shortened from above downwards in proportion to the relative sizes of diameter of tube and cistern, but the highest point of the scale is correctly marked from a definite point which is marked on the side of the cistern. In the Marine form, the only difference is that the tube is contracted at some part of its length to prevent oscillatory movement due to motion of the ship.

2. The Siphon barometer is of quite different construction. It has no cistern whatever, but a U-shaped tube is substituted in its place. The U consists of a long leg and a short one, the former being closed, the latter open. As the mercury rises in the long limb, it necessarily falls in the short one ; as a consequence, a reading must be taken from each side. No capillary correction is required for this instrument, and it is probably the best mercurial instrument for mountain ascents.

3. *The Wheel Barometer.*—This is practically a modification of the siphon instrument, in respect that a float placed in the open short limb rises or falls as does the column of mercury, which float, by means of a string and block, transfers motion to a lever acting like the hand of a clock, and is magnified on a dial, which is prepared from observations. This instrument has also been used to record automatically by suitable mechanical arrangements the rise and fall of the mercury, and is then called a *barograph.*

Fig. 112.—Mine Barometer.

In addition to mercurial barometers, there are other instruments for measuring the atmospheric pressure, viz. :—

(*a*) The Sympiesometer ;
(*b*) Aneroid Barometer.

The *Sympiesometer* (or a measurer of compression), known as Adie's instrument, consists of a glass tube, 18 inches in length and $\frac{3}{4}$ of an inch in diameter, which has a small chamber at the top and an

open cistern below. This upper chamber and upper part of the tube contain air, and the remainder of tube and the cistern are filled with glycerine. As the atmospheric pressure increases, the air in the upper part of the instrument is compressed and the glycerine rises; should the pressure on the other hand diminish, the air expands and the glycerine-level falls. It is graduated by comparison with a mercurial barometer, but owing to the respective different densities of mercury and glycerine the intervals corresponding to inches in the one become much greater in the other and are of unequal length, being shorter as the tube is ascended. To the instrument are added a thermometer and a sliding scale which can be adjusted for the temperature found at each observation. It is a very sensitive instrument.

The *Aneroid* Barometer.—This instrument is extensively used by reason of its compact form and portability, and depends for its action upon the changes in form which a thin metallic box, in a condition of partial vacuum, experiences on differing degrees of pressure. The greater the pressure of the atmosphere the greater the compression of the metallic box; when the pressure becomes less, the box is replaced to its former state by a spring. The instrument essentially consists of, (1) a vacuum chamber which is composed of two discs of corrugated German silver formed into a box-shape by soldering; (2) a base-plate. The vacuum chamber is attached to the base-plate by one pin, and to a strong spring by another pin which is borne by the frame of the instrument. The spring acts in opposition to the movement of the walls of the vacuum chamber. Attached to the spring is a lever composed of iron and brass—intended to act as compensation for temperature—which is connected by another bent lever to a chain wound round the *arbour*. The spiral-spring keeps the chain tightly wound round the barrel, and the chain operates on the hand or index which moves over the dial-face, by reason of the rotatory action of the barrel. These instruments are all graduated and compensated for temperature, are good, and are at first sensitive instruments, but they are liable in time to become inaccurate from imperfect workmanship, corrosion, and other causes.

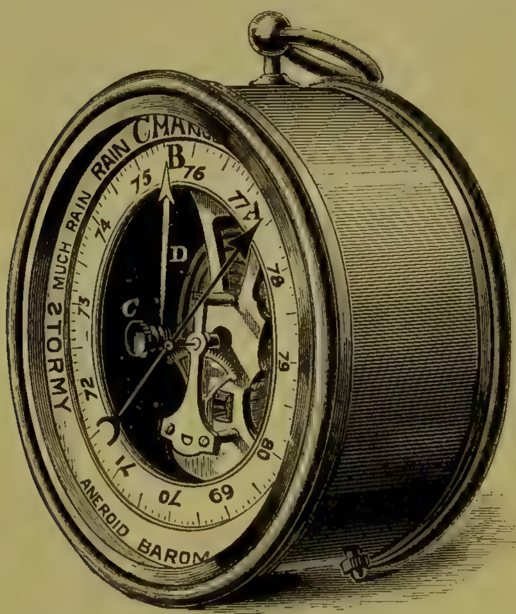


FIG. 113.—Aneroid Barometer.

Defects in Mercurial Barometers.—The presence of air or moisture in the Torricellian space renders an instrument useless by reason of inaccuracy, inasmuch as the expansion of contained air, or the elastic force of watery vapour, tends to counterbalance the pressure of the

outside atmosphere, and to cause the mercury to act sluggishly. If a barometer tube has been properly filled, by tightly stopping the lower open end with a finger and suddenly depressing the closed end, a sharp, metallic click of the mercury against the glass will be heard. Ingenious arrangements have been made to prevent the access of air or moisture, but in modern instruments these are not commonly found. In order that barometric observations in different places may be comparable, the readings must conform to certain standard conditions, for which the barometer requires corrections. Such barometric corrections must be considered, (1) with reference to the individual instrument; (2) with reference to all mercurial instruments. Those necessary for any individual instrument are (*a*) *index error;* (*b*) *capacity;* (*c*) *capillarity.* The index error includes errors of graduation of the scale of the instrument, and the position of the zero of the scale; the latter makes readings of the instrument either too high or too low, the former are often different for different parts of the scale. These are rectified by comparison with a standard instrument at Kew, and the corrections are supplied with the certificate. Correction for capacity is not usually required in the newer instruments. When present, however, its amount depends on the proportion of the sectional area of the tube to that of the cistern. Correction for capillarity is sometimes needed since a certain amount of capillary action occurs between glass and mercury which tends to depress the mercurial column. This is liable to be greater the smaller the bore of the tube.

The corrections common to all readings of instruments are two in number, viz.: (*a*) for temperature, (*b*) for altitude. *For Temperature.*—Mercury expands by heat, consequently a heated column of that metal gives a higher reading. It is therefore necessary to reduce the reading to the temperature of the freezing-point of water, which is commonly called the "reduction to 32° F." The co-efficient of expansion of mercury for each degree Centigrade is ·00018018, and for each degree Fahrenheit, ·0001001 above freezing-point. *For Altitude.*—Since altitude affects the reading of a barometer by reason of differences of pressure, it is necessary to correct the reading of every barometer to a standard level, which, for Great Britain, is *the mean half-tide level at Liverpool*, and the correction is thus known as the "reduction to sea-level." The altitude of any place of observation above this level may be ascertained from the Ordnance Survey maps. The simplest, and at the same time, fairly accurate rule is to estimate the difference of the readings of the barometer between the point at which the observation is taken and the sea-level in hundredths of an inch, and to multiply by 9; the result gives the difference in altitude in feet. This method is based on Strachan's observations that a height of ninety feet gives a difference in barometric reading of 0·1 of an inch.

The term "*isobar*" means a line of equal barometric pressure, and as the force of the wind depends upon differences of pressure, these differences of pressure between isobars of different pressures are termed *gradients*, which is a term expressive of such different lines or points of pressure over a given distance. The units of pressure and distance in this country are respectively 0·1 inches

and fifteen geographical miles, or in the metric system, one millimetre and one degree or sixty geographical miles. These isobars or lines of equal pressure assume certain typical forms, and determine the force and direction of winds. Of these forms the principal are (*a*) the cyclone, (*b*) anti-cyclone, (*c*) V-shaped depressions, and (*d*) straight isobars. The cyclone is characterised by concentric isobars, the lowest pressure being found in the centre, the gradients being steep. The anti-cyclone is also characterised by concentric isobars, less definite, however, and further apart, the highest pressure being in the centre, the gradients being less steep than in the cyclone. In V-shaped depressions or wedges of low pressure, the pressure is highest in the interior, and they are usually found between two adjacent anti-cyclones. There are also wedges of high pressure between two adjacent cyclones. In cyclonic areas of pressure, the wind blows spirally or obliquely into the centre, which is the point of lowest pressure, in the reverse movement of the hands of a clock, whereas in anti-cyclones the wind blows spirally or obliquely from the centre—the point of highest pressure—to the circumference, in the direction of the hands of a clock. From such distributions of pressure weather conditions are forecasted. From the steepness of the gradients—that is, the differences in pressure and distance of the isobars—in a cyclone, strong high winds and stormy wet weather may be predicted, followed by bright sunny weather. In anti-cyclones the weather is good; there is little wind, and the air is bracing. Such, however, are apt to be attended by fogs in towns and cities.

Since weather conditions, such as dull, foggy, and wet days and lowered temperatures, provoke disease, these meteorological facts are not without interest to the medical officer of health.

PHYSIOLOGICAL EFFECTS OF ABNORMAL ATMOSPHERIC PRESSURES.

Man has so long been accustomed to live within limited distances at or above the sea-level, that it is difficult to acclimatise him, without risk to health or even life, to pressures which are either markedly greater or less than normal. Hence it is, that by the utilisation of compressed air at pressures greater than normal, by which so many important engineering schemes have been carried to a successful issue, and without which none could have been attempted, men have to be subjected at some risk to life and health to increased atmospheric pressure during their hours of labour. The main physiological effects perceptible to one in an atmospheric pressure of about 24–27 lbs. per square inch are mainly as follow: first, a sense of fulness in the head in the neighbourhood of the internal ear accompanied by deafness. This is due to the unusual pressure exercised upon the tympanum from without, and the want of equilibrium of air-pressure in Eustachian tube and outer ear on that structure. The foregoing sensation may, therefore, be largely, if not entirely removed by Valsalva's method of inflating the Eustachian tube, or by performing frequently the act of swallowing. Should this manœuvre not be adopted, rupture of the tympanum may ensue. Second, pains in the forehead over the frontal

sinuses, with or without accompanying epistaxis. Third, owing to the rise of blood-pressure and increased action of heart, hæmoptysis may occur. Fourth, there is some degree of arterialisation of the blood of the superficial veins of the body. Some of these effects we have personally experienced during visits to underground works in which the pressure was as named above. In workmen who are, however, exposed to such pressures for hours on end, more serious results may ensue, as for example faintings, pains in limbs and joints, with tenderness on pressure over the seat of the pains, epigastric pains, with or without nausea and vomiting, and paresis or even motor and sensory paralysis of limbs. A pale, earthy, or leaden appearance of countenance has also been observed in workers in compressed air. Snell[1] attributes this last condition to the effects of imperfect ventilation. This author goes so far indeed as to affirm that the amount of illness found in such workers is largely attributable to the want of ventilation in the working-place. There is no doubt that the percentage quantities of CO_2 found in the working-place is often very high.

Mountaineers and balloonists on the other hand suffer from the effects of abnormally low pressures and from the deficiency per cent. of oxygen which such low atmospheric pressure indicates. *Mal de montagne* is a well-recognised affection, the chief symptoms of which are severe headache, great ennui and inability for exertion, and panting for breath. According to Hepburn,[2] true mountain sickness only supervenes at altitudes at and above 16,500 feet. The conditions of the mountaineer are, however, somewhat different from those of the aeronaut; those of the former are most largely due to diminution of oxygen per unit volume of air, whereas those of the latter are mainly attributable to reduction in pressure, as well as to diminution of oxygen.

[1] "Compressed-Air Illness," 1896.

[2] *St. Barth. Hosp. Reports*, 1895.

CHAPTER IV.

AIR AND VENTILATION.

Air—*Composition.*—The purity of the air or atmosphere only becomes an urgent question when Man congregates in large numbers within a small area, and lives within spaces bounded by walls; for under these conditions only is air likely to become so impure as to affect prejudicially the health of those so situated.

Pure air per 1000 volumes has the following constitution:—

Average Composition of Pure Air per 1000 *Volumes.*

Nitrogen (including *argon, helium, neon, krypton,* and *zenon*)	= 779·0600
Oxygen	= 206·5940
Watery Vapour (as a gas)	= 14·0000
Carbonic Acid, or Carbon Dioxide	= 0·3360
Ammonia	= 0·0080
Ozone	= 0·0015
Nitric Acid	= 0·0005
Total	1000·0000

If we leave out of count watery vapour, which is variable in amount, then in 1000 volumes the composition may be said to be as follows:—

	By Volume.
Oxygen	= 209·6
Nitrogen	= 790·0
CO_2	= ·4
	1000·

For many years the principal gas in the air, apart from oxygen, has been reckoned as nitrogen, but the recent investigations of Lord Rayleigh and Professor Ramsay, and others, have demonstrated the presence in small quantities of the gases which we have included above in Nitrogen. They have proved that 100 vols. of pure air contain 0·937 volume of these combined gases, of which argon is the principal component, being, in that quantity, about 400 times greater in amount than the other four put together. Moreover, the physical triumph of the liquefaction of air has made such researches as the chemical composition of air more fertile in results. In addition, however, to these discoveries, Armand Gautier has demonstrated that pure air contains small but appreciable quantities of free hydrogen and of marsh gas (CH_4). In the air of Paris, as a type of impure air for example, while the presence of free hydrogen was detected upon isolated occasions, the CH_4 amounted to ·226 vols. per 1000 of air. In the air of forests, where it might be expected that marsh gas would be more plentiful by reason of the decomposition of vegetable substances, that gas only

amounted to half that quantity, viz. ·113 vols. per 1000; while at a height of 9000 feet in the Pyrenees, amid snow, his experiments demonstrated a still further diminution of CH_4 to ·0219 vols. per 1000, whereas the amount of free hydrogen had increased to ·17 vols. per 1000 volumes of air. While, therefore, the principal constituents of the atmosphere may be reckoned to consist of Nitrogen, Oxygen, Carbonic Acid, Ozone, and watery vapour, it does not appear as if its complete chemical constitution was quite so simple as has hitherto been believed.

Oxygen, which so far as human life is concerned may be reckoned as its most important constituent, amounts in the purest air to 20·96 per cent.; but this amount may be appreciably lessened under different circumstances. In breathing, for example, where the oxygen taken into the lungs replaces the carbonic acid gas of the blood, the composition of the expired air differs enormously from that of inspiration. In 1000 vols. of the former, oxygen = 169·2, nitrogen, etc., = 790·4, and carbonic acid = 40·4 volumes. The other factors which reduce the amount of oxygen are combustion, fermentation and putrefactive processes, manufacturing and trade operations, organic matter in suspension in the air, and others; while those that are restorative of oxygen are mainly the action of vegetable life in splitting up CO_2 in the presence of sunlight into carbon and oxygen, by which the carbon is fixed by the plant and oxygen is liberated, the physical influences of currents of air, and the rainfall. It has been clearly demonstrated that the amount of oxygen in the atmosphere of populous places for the above reasons undergoes a sensible diminution. Angus Smith showed that during frost and fog in the air of Manchester it fell to 20·910 per cent.

Experiments have demonstrated that it is possible for a man to breathe, for a very limited time only without insensibility supervening, an atmosphere which contains only 16 per cent. of oxygen and 4 per cent. of carbonic acid. But remarkable cases occasionally are found. During the construction of a railway bridge over the river Forth near Alloa, in 1882, one man lost his life and the lives of two others were endangered under the following circumstances. The piers of the bridge consisted of hollow iron cylinders. These consisted of segments each about 6 feet in height, which were placed above one another till they reached a total length of 60 feet before the pier was finished. At the junction of each two segments, a space was left all round which had to be filled by a workman from the inside of the pier with a rusting composition which was made up of iron turnings, sulphur, and the addition sometimes of ammonium chloride. One warm, still day in summer, a workman employed in filling up this space with this composition was observed to appear as if overpowered in some inexplicable way. A companion went down to his rescue in a bucket suspended by a rope, placed the man into the bucket, and he was hauled up and revived shortly after. His rescuer, however, in turn became similarly overpowered, and fell into a pool of water at the bottom of the cylinder, in which he was drowned. One of the contractors, after tying a rope round himself, was lowered to the rescue, was likewise overpowered, but was speedily hauled up, and quickly recovered. It was evident that the cause of the mischief was some lethal gas, but what was its precise constitution was not known. The

late Dr. Wallace, then analyst to the city of Glasgow, came to the conclusion that the cause might be related in some way to the rusting composition used. Having obtained some of the material for experimental purposes, he quickly discovered that when the substances composing it were mixed in a limited quantity of air, the oxygen became so rapidly absorbed that after ten minutes' action the air would not support the combustion of a candle, and that at the end of two hours the amount of oxygen absorbed amounted to 16 parts per 100 volumes of air. Exposure for a still longer period indicated a loss of 20½ parts of oxygen per 100 volumes of air, or nearly the whole amount of oxygen present. Another noteworthy phenomenon observed during the oxidation of the iron of the composition was the considerable rise of temperature of the air, which in one of the experiments reached 156° F. It thus became evident that the cause of the attacks was the limited supply of oxygen due to the oxidation of the iron of the rusting composition, and to the want of circulation of air in the confined space.[1]

Nitrogen serves the useful purpose of diluting the oxygen in the air for the needs of men, animals, and plants, and moreover is an important factor in plant nutrition, since not only are portions of it converted during thunderstorms into nitric acid which is washed into the soil for plant use, but plants, like those of the leguminous order, through the agency of bacteria contained in nodules on their roots, are able to fix the free nitrogen of the air. For the above reason, infinitesimal proportions of nitric acid are sometimes found in the air.

Ozone, which is an allotropic form of oxygen with the chemical formula of O_3, is only found in the air of mountainous regions and of the sea and sea-board especially after thunderstorms, and even then in but small proportions. Because of its property of being rapidly and readily oxidised by organic matter in the air, it is not found in the atmospheres of large populous places.

Carbonic acid may be deemed a normal constituent of air up to a certain point, because of the oxidation of carbon which takes place in Nature, but beyond a certain proportion, it must be reckoned as an impurity. Existing in the purest air from ·0336 to ·04 per cent., it may be found in the air of populous places in winter to the extent of ·0539 per cent., and in the atmosphere of inhabited, ill-ventilated dwellings, even of one per cent. and upwards. In the Cotton Cloth Factories (Amendment) Act, 1887, it is enacted that the air of such factories must not contain more than 0·9 CO_2 per 1000 vols. of air.

Watery vapour is a variable constituent in air, its amount fluctuating considerably, depending mostly upon temperature. The average amount is about 1·4 per cent. In cotton-cloth factories, two sets of standard wet-and-dry bulb thermometers must be kept, and daily readings taken between 10–11 A.M., and 3–4 P.M., of which a record must be kept.

Ammonia is always found in impure air, but only in infinitesimal proportions, the average amount not being more than one part per million.

Characteristics of Impure Air.—The air of a populous place differs in its composition from that of the open country or the sea in respect that it contains many impurities, and of different kinds. These may be divided into two main classes, viz. : (1) *Particulate*, (2) *Gaseous*. The causes which determine the presence of both are the artificial con-

[1] *Proc. Phil. Soc. Glasg.*, vol. xiv. p. 1.

ditions contingent upon the congregation of Man and animals in a limited area. The former impurities consist of (*a*) unconsumed particles of coal-débris, in the form of soot-particles; (*b*) débris from the bodies of men and animals, from street-traffic, and from industrial operations, of organic and inorganic composition; (*c*) spores of plants, pollen, bits of decaying vegetation, fibres of different stuffs; and (*d*) micro-organisms. The particulate bodies are the main causes of fog, since round them are formed halos of condensed watery vapour. The colour and density of fogs are determined by the amount of smut particles present. It is for this reason that in populous places fogs assume a brown colour and dense character, whereas in the country they are light in colour and have the appearance of mist. Aitken has devised an ingenious apparatus by which the number of particles present in a unit quantity of air may be computed. He has demonstrated that the number of particles per cubic inch of air ranges in number from about 2000 in the air of the open country, to three millions and upwards in populous places. Such particulate bodies, when inspired, generate pulmonary affections because of their irritant character, an action which is seen in more marked degree in persons engaged in certain occupations in which particulate matter of varying kinds is thrown into the atmospheric environment of the workers, and the intensity of which depends largely upon the character of the particulate matter, being more severe where it is of a gritty, angular character than when composed of a soft, fluffy composition. Perhaps of greater importance, however, is the presence of micro-organisms. That their number is greatest in populous centres is demonstrated, as might be expected, by the fact that on mountain-tops, and far out at sea, their number is reduced to a minimum; indeed, from the experimental researches of Miguel, Fischer, and others, it has been shown that in high altitudes the average number is reduced to *one organism per cubic metre of air*, and far out at sea, to the vanishing point. Even in the air of a populous place, however, Frankland, Carnelly and others have shown (1) that the number of micro-organisms per unit quantity of air is greatest where persons most do congregate in confined spaces, as in halls, schools, churches, and like large buildings; (2) that from the effect of gravity the number is greatest on the ground-level, and diminishes by altitude; (3) that after rain or fog the numbers diminish, due to the rain washing the organisms on to the streets, or into the soil. Hence in populous places air-borne infection is more prevalent than in the open country.

Of the gaseous impurities, the chief are (1) Carbonic Acid and Carbon Monoxide from the lungs of men and animals, as a product of combustion of coal, of trade processes, and of coal-gas in the air of houses; (2) sulphur gases, as sulphurous acid, sulphuric anhydride, sulphuretted hydrogen; (3) ammonia, as such and in combination with sulphuric acid and sulphuretted hydrogen; (4) other gases from chemical works, etc. The Alkali Acts enact that not more than one-fifth of a grain of HCl and four grains of SO_3 per cubic foot should escape from the works into the air.

Examination of Air for Particulate Bodies.—I. This may be carried out roughly by placing microscope glass slips, moistened with glycerine over one square inch of surface, in different situations and with

different time-exposures, in the place to be examined; and thereafter, by examining the slides microscopically with high and low powers of microscope.

II. *By Pouchet's Aeroscope.*—This instrument consists of a funnel-shaped tube drawn out to a point which closely impinges upon a slip of glass moistened with glycerine. These are enclosed in an air-tight chamber, which is connected with an aspirator. As the water of the aspirator runs out slowly, air passes into the apparatus, and any particles which it contains are arrested by the glycerine. The glass slip is then taken out and examined by the microscope. Since any definite quantity of air may be aspirated, the number of particles in a given quantity of air may be estimated. For the estimation of the number of micro-organisms in air, probably the best apparatus is that of Hesse, or some modification of it. It consists of a hollow glass cylinder, one end of which is covered by a double india-rubber cap, the other end being connected with an aspirator of known capacity. The cylinder is first of all carefully sterilised, thereafter it is coated with sterilised nutrient gelatine, and the whole is then sterilised for three successive days, to ensure the absence of any contained organisms. The cylinder is then mounted on a tripod stand, and is ready for use. The outside rubber-cap being removed, a small puncture is made in the inner rubber cap, the aspirator is started in action, and air is thus slowly drawn through the cylinder, the micro-organisms being deposited on the gelatine coating. At the end of the experiment, the quantity of air which has been passed having been noted, the cylinder and contents are incubated, and the number of colonies which grow can then be counted with relation to the quantity of air aspirated. Instead of using a coated cylinder, however, Frankland prefers to use a tube which contains sterilised sugar as a packing or filter for the arrest of the organisms, which at the end of the experiment can be melted in sterilised water in sterilised flasks, and after incubation the number of organisms may be counted.

Another method is to expose for different short periods of time the sterilised contents of Petri capsules, the square area of which in inches or millimetres is known, in the atmosphere the microbic contents of which it is desired to examine.

The methods of estimating the impure gases in air will be considered when the subject of ventilation is considered.

Space in Reference to Air-Supply.—The kinds of space of importance with relation to air-supply are superficial space and cubic space, and the one not less than the other. The former is sometimes called floorage. In dealing with the dimensions of any confined space bounded by walls and roof when considering adequacy of ventilation, regard must be paid to both dimensions. Cubic space, alone, is not enough, since it may be made up in various ways in a confined space. For example, a room might be constructed to contain 10,000 cubic feet of air by very different dimensions, viz. :—

	Length.		Breadth or Width.		Height.	Cubic Feet.
(a) . .	50	×	20	×	10	= 10,000
(b) . .	25	×	40	×	10	
(c) . .	20	×	25	×	20	
(d) . .	16	×	25	×	25	

But when these proportions are examined with reference to habitability it will be apparent that they are by no means equally suitable. A room, for example, which was only 20 feet long would be ridiculous if 25 feet in height, and, much more so, if of a like height and only 16 feet in length. If, for a moment, we suppose that such a room was to be occupied as a school-room under the requirements of the Education Act of 1870, which demands for each child a floor-space of 8 square feet, and a cubic space of 80 feet, then $10{,}000 \div 80$ will give the number of scholars for the cubic space as 125. Under the spacings of (*a*) and (*b*) the requirements could be fulfilled; but under spacings (*c*) and (*d*) they could not be, since in the former the available floor-space per child is only 4 feet, and in the latter only $2\frac{2}{5}$ feet. It is therefore clear that in considering the dimensions of any room intended for occupancy, the relations between superficial and cubic space must bear a certain relation to one another with special reference to the possibility of adequate ventilation. This is true of all rooms, whether occupied by healthy or sick. In the latter case, especially, each dimension of space must be increased, and particularly in isolation hospitals, where the minimum superficial space ought not to be less than 144 square feet, and the cubic space than 2000 feet. The following Tables show the cubic space required by law per person in certain conditions of life, and the school spaces which exist in different countries.

Table XI.

Table Showing Cubic Space Allowed by Law.

Cubic space allowed by Law or Local Regulations.	Cubic space per head.	Authority.
Board Schools under Education Act . .	80	Education Act.
Board Schools (minimum under New Code)	100	Education Department.
General school-rooms	130	London School Board.
Graded schools	117	,, ,,
Dundee Board schools—newest . .	152	Dundee School Board.
Canadian schools	240	Canadian Government.
Ordinary dwelling-houses in Glasgow and Edinburgh, in one and two-roomed houses—for adult	400	Glasgow Police Authority.
Two children under 10	400	Glasgow Police Authority.
Common lodging-houses	240–400	
Poor Law for healthy persons . . .	300	
Poor Law for sick persons . . .	850–1200	
Barracks	600	Army Regulations.
Army hospital wards	1200	,, ,,
,, Huts (free ventilation) . . .	400	,, ,,
,, Hospital	600	,, ,,
Canal boats (persons over twelve) . .	60	Local Government Board Regulations under Canal Boats Act, 1877.
Do. (persons under twelve) . .	40	
Seamen's cabins	72	Merchant Shipping Act.
Non-textile workplaces	250	Factory Act, 1895.
Do. Do. (during overtime) .	400	

TABLE XII.

TABLE SHOWING SCHOOL SPACES IN DIFFERENT COUNTRIES.

Country.	Superficial Floor Space in Square Feet.	Cubic Space in Feet.
Great Britain (Government Code)	10	100 to 140
London School Board	...	130
Dundee School Board	...	152
Canada	...	240
Belgium	10½	160
,, Educational League	17½	338
Holland (average)	...	131
,, Haarlem (average)	...	160
Bavaria (children of eight years)	...	137
,, (children of twelve years)	...	197
Dresden	7	152
Frankfort (Med. Society)	15½	300 to 325
Basle (Switzerland)	15½	148 to 165
Sweden (Primary schools)	16	188 to 266
,, (Higher schools)	17 to 23	271 to 352
America (New York City)	...	88 to 105
Columbia (Commission)	15	210
Massachusetts (State)	Demands that each pupil receive 1800 cubic feet of warmed fresh air per hour.	

Taken from a paper by the Author on "The Hygiene of Schools" in the *Sanitary Journal*, January, 1895.

Effects of Occupation of Rooms, or other Confined Spaces.—If an ill-ventilated room be occupied for two or more hours, the following changes will be found in the composition of its air at the end of the term of occupancy, viz. :—

(*a*) The temperature will be raised ; due to the heat from the bodies of the occupants, quite apart from any other source, as artificial lights ;

(*b*) Watery vapour is increased in quantity ; due to exhalation from the lungs and body-surface of occupants ;

(*c*) Amount of carbonic acid gas per cent. will be increased ;

(*d*) A disagreeable odour will be imparted to the atmosphere.

These facts are explained in the following: An average male adult inspires 30·5 cubic inches of air at each breath, and he inspires about seventeen times per minute ; the total quantity of air which he will breathe in 24 hours will, therefore, be the sum of the following calculation, viz. :—

$$30{\cdot}5 \times 17 \times 60 \times 24 = 746{,}640 \text{ cubic inches} = 432 \text{ cubic feet.}$$

Women and children use a less daily amount of air than this. The expired air, if we contrast its composition with that of fresh air, contains 101 times more carbonic acid gas than the latter, and further, it contains much watery vapour from the surfaces of the air-passages, varying in different persons at different times from 3½ to 45 ounces, or even more per 24 hours. In addition to these, organic débris in a

state of incipient putrefaction is given off from the breath and bodies of the occupants, which imparts to the air of the room a close, disagreeable, or even foul odour. This expired air is thrown out of the body at a temperature of about 100° F. The average adult gives off, in ordinary circumstances, at least ·6 of a cubic foot of CO_2 per hour, or 14·4 cubic feet per 24 hours.

If, in addition to human occupation, artificial lights be used in a room, the increase of temperature and of CO_2 are even greater. A gas-jet which consumes about 4 cubic feet of gas per hour produces about 2 cubic feet of CO_2 per hour; and in like manner acetylene, oil, and other illuminants contribute to the sum of this gas. As has already been shown, CO_2 exists in pure air to the extent of ·04 per cent. This is called the *original* or *initial impurity*. Any excess over that figure in the air of a room represents the amount due to respiratory and other causes, as artificial lights, and hence that is called the *respiratory* impurity. Both added together are called the *total impurity*. The odour of the air of a room depends upon the presence of organic matter, and the measure of its amount is indicated in three ways, viz.: (1) by the sense of smell to a person coming into the room from the fresh air; (2) by the amount of CO_2 present and found on analysis; and (3) by direct estimation of the organic matter itself. When the proportion of the respiratory impurity of the total CO_2 in air is not greater than ·02 per cent., no disagreeable odour is perceived, but above that proportion odours become perceptible: thus ·08, *i.e.* ·04 initial + ·04 respiratory impurity, causes a stuffy odour; ·10 (*i.e.* ·04 + ·06), an offensive odour; and ·12 (*i.e.* ·04 + ·08), a foul sickening smell. Beyond this point the sense of smell fails to discriminate. Moreover, in atmospheres containing these latter proportions of CO_2, flushings, faintness, headache, and even sickness are liable to be induced. The pernicious effects of foul air are doubtless attributable to the combined effects of excess of CO_2 and organic matter. It is impossible to discriminate between the effects produced by the operations of these singly, since from occupation of imperfectly ventilated rooms they are closely associated together. Most observers, however, are inclined to attribute the evil effects mainly to the organic matter which is given off from the bodies of occupants of a room, and which consists of varied materials, partly volatile fatty acids from the skin which are given off by the sensible perspiration, and in certain individuals and nations more markedly than in others, and also of intestinal gases and products of decomposition from soiled clothing. Of late years, however, certain investigators have arrived at the conclusion that these last are not so prejudicial to health as was believed, and indeed that the baneful factors in impure room air are chiefly excess of CO_2 and decrease of oxygen. The experiments of Haldane and Lorrain Smith indicate at least that immediate danger is caused by these factors, but they do not in our view weaken the conclusion generally held, viz.: that constant exposure to air contaminated with organic matter is more contributory to the generation of lowered health and disease than the presence *per se* of excess of CO_2. There can be little doubt that where persons are more or less constantly exposed to atmospheres containing fractional proportions of carbon monoxide, or of coal-gas, ill-

health, as exhibited by anæmia, mal-nutrition, and other symptoms, will quickly supervene, owing to the union of this gas with the hæmoglobin of the blood, and to its crippling action upon the function of the blood-corpuscles to carry oxygen to the tissues. That organic matter is particulate in part at least, is demonstrated by the fact that articles of attire retain the disagreeable odour for some time after exposure to fresh air, and that bedclothing in such a room retains it for a very long time. The painstaking investigations of Billings, Mitchell, and Bergey,[1] led these observers to conclude, (1) that in air expired by man there is no peculiar organic matter which is poisonous to mice, sparrows, rabbits, or guinea-pigs, and that it is improbable that the minute quantity of organic matter expired from human lungs is hurtful to those inhaling it in ordinary rooms; (2) that the ammonia, combined nitrogen, or other oxidisable matters found in the condensed watery vapour of expired air of man probably arises from decomposition of organic matter in the pharynx and mouth; (3) that the results should be more properly ascribed to the diminution of oxygen and increase in carbonic acid gas; and (4) that the cause of the disagreeable odour which is perceptible in ill-ventilated, occupied rooms is not precisely known, but is probably due to volatile products given off from the mouth and skin, and from soiled clothing. In order to maintain health, therefore, it is essential that the amount of CO_2 should be kept as near ·06 per cent. as possible, of which ·04 is initial, and ·02 respiratory impurity.

VENTILATION.

In order to maintain purity of air in inhabited rooms it is essential, therefore, that the fouled air should be got rid of to give place to the fresh air. This is effected by means of ventilation. *The problem of ventilation consists in supplying in a given space to a given number of persons in a given time the necessary physiological amount of fresh air without draught.* Physiological requirements indicate 3000 cubic feet of pure air per hour as the supply to be aimed at, and the rate of movement of the incoming air must not exceed $1\frac{1}{2}$ to 2 feet for delicate persons, and for average persons $2\frac{1}{2}$ to 3 feet, per second, else draughts will be perceived. Should the air be warmed, however, the velocity may be raised to 5–8 feet per second. This is the crux of the problem of ventilation, and hence the dimensions of space per person in a room assume great importance. When the Glasgow Sanitary (Further Powers) Bill was before a Parliamentary Committee, it was contended as a reason why the cubic space per person should be raised from 300 to 400 cubic feet, that the possibility of ventilating such small one- and two-roomed houses might be realised. As a matter of fact, however, while ventilation might be improved in the better of these conditions it could not adequately be carried out, as the following figures will show. An average-sized one-roomed house contained 1060 cubic feet. Under the previous Act, it was entitled to house three adults and one child.

[1] "The Composition of Expired Air and its Effects upon Animal Life," p. 24.

As each adult requires 3000 cubic feet of air

∴ $3\frac{1}{2}$ adults × 3000 . . .	=	10,500 cubic feet.
At night, with an ordinary gas-jet burning 3–4 cubic feet of gas, the air-supply needed for that	=	6,000
Total . .	=	16,500 cubic feet required per hour.

The air needed per hour being 16,500 cubic feet, and the cubic capacity of the room, 1060 feet, it is obvious that the air of the room would need to be changed—16,500 ÷ 1060—say, 15 times per hour; in other words, 1060 cubic feet would require to enter in four minutes, or 4·4 feet per second. This rate of velocity produces draughts, to prevent which the inlet openings are blocked up by the occupants. Under the proposed alteration of 400 cubic feet per adult, and half that amount for a child under twelve, the rate of velocity, all other things equal, would only be reduced to about 3·8 feet per second. Again if we suppose two rooms, each of 1000 cubic feet capacity, to be occupied as bedrooms by one and by four adults respectively, a little calculation will show that in the case of the former the necessary amount of air could be supplied to fulfil the physiological needs of the individual and without draught, since the air would enter at a velocity of ·8 of a foot per second, but that in the latter the supply of the requisite amount of air would be accompanied by draughts, since the velocity of the entering air would be over 3 feet per second.

The amount of CO_2 being then a measure of the impurity, organic and inorganic, of the air of an occupied place, and the amount of this gas normally present in pure air being known, by an estimation of its quantity in the air of any given room it is possible (1) to determine the volume of air which is being supplied to the room, and (2) if it be inadequate in volume, to what extent the inadequacy prevails. Du Chaumont's formula is as follows:—

Let p = amount of CO_2 present in one cubic foot of pure air;
P = amount of CO_2 in terms of a cubic foot given off by each average person per hour;
A = amount of air in cubic feet required, or introduced per hour, the same amount escaping by outlets;
π = Impurity of the air in terms of CO_2 which results.

Known by estimation:—

p = ·04 per cent., or ·0004 CO_2 per cubic foot in pure air;
P = ·6 cubic CO_2 in expired air per person per hour.

From these factors two formulæ may be constructed:—

1. To determine the volume of air per hour in cubic feet required by each average person in order to maintain respiratory impurity at ·02 per cent.
2. From the CO_2 found, to ascertain the amount of fresh air which is delivered to each occupant per hour.

For the first calculation the formula becomes—

$$A = \frac{P}{\pi - p} = A = \frac{\cdot 6}{\cdot 0006 - \cdot 0004} = 3000 \text{ cubic feet per hour.}$$

But p being practically a constant, the formula may be shortened as follows, viz. :—

$$A=\frac{P}{p}.$$

$$A=\frac{0{\cdot}6}{{\cdot}0002}=\underline{3000} \text{ cubic feet per hour.}$$

Three thousand cubic feet of air per hour, therefore, is the amount required by the average adult person to maintain the total impurity in the air of a room at the healthy minimum, in terms of CO_2, viz., ·06 per cent., of which ·04 is original impurity, and ·02 respiratory impurity.

Example.—A room of 1000 cubic feet capacity is occupied by five adults for four hours: it is required to find the total amount of CO_2 per 1000 vols. of air at the end of that time, on the assumption that during the time of occupation 5000 cubic feet of fresh air per hour have been supplied?

In this problem the values of A, P, and p are given; and what is required is to find the value of π, the permanent impurity:

$$\text{Value of } A\begin{cases}\text{cubic capacity of room} \quad . \quad . = 1{,}000 \text{ feet.}\\ \text{air supplied during the time,}\\ \quad 5000 \text{ feet} \times 4 \text{ hours} \quad . \quad . = 20{,}000\end{cases}$$

$$\text{Total} \quad . \quad . = 21{,}000 \text{ cubic feet.}$$

Value of P: $0{\cdot}6\times4=2{\cdot}4\times5$ persons $=$ 12 cubic feet CO_2.
= amount of CO_2 contributed by five persons during four hours' occupancy.

$$\therefore \frac{P}{A}=\frac{12}{21{,}000}={\cdot}00057 \; CO_2 \text{ per cubic foot of air of room, or}$$

$$={\cdot}00057\times1000={\cdot}57 \text{ parts } CO_2 \text{ per 1000 cubic feet.}$$

But $p=$ ·4 parts of CO_2 per 1000 vols. of pure air which is supplied.
Therefore, $\pi={\cdot}57+{\cdot}4={\cdot}97$ parts CO_2 present in air of room; or the resulting permanent impurity.

The second use of the formula is to determine from the CO_2 found the amount of fresh air which has been delivered during a given time to all, or each of the occupants of a room per hour.

Example.—The air of a room occupied by five adults is found to contain 9·7 vols. of CO_2 per 10,000 vols. of air: it is required to find the total amount of fresh air supplied per hour, and the amount to each occupant.

The problem here is to find the value of A.

$$A=\frac{P}{\pi-p}.$$

Value of $P=0{\cdot}6\times5=3$ cubic feet of CO_2 of respiratory impurity given off by five persons during one hour;
,, ,, $p=0{\cdot}4$ CO_2 per 1000 cubic feet of air; or ·0004 per cubic foot.
,, ,, $\pi=0{\cdot}97$ CO_2 per 1000 cubic feet of air; or ·00097 per cubic foot.

$$\text{Therefore, } A=\frac{3}{{\cdot}00097-{\cdot}0004}=5263 \text{ cubic feet for five persons;}$$

or, $5263\div5=1052$ cubic feet per person.

Another common formula in use is—

$$D=\frac{E}{r}.$$

Where $D=$ delivery, or amount of fresh air available in cubic feet;
$E=$ amount of CO_2 given off;
$r=$ respiratory impurity in terms of CO_2 per cubic foot.

The analyses of Carnelly and others of the air of sleeping apartments during the early hours of the morning show (1) that the quantity of CO_2 has a distinct relation to the amount of air supplied to the apartment. It amounted from 0·79 vols. per 1000 of air, where the air-supply per head was between 2500 and 4000 cubic feet, to 0·92, where the supply was from 340–500 cubic feet, and up to 1·15 per 1000, where the supply was so low as from 100 to 180 cubic feet; (2) that the organic matter, estimated in terms of oxygen required per million volumes of air, with the same supplies of air as above, was 5, 8·4, and 15·1 parts per million respectively; and (3) that the number of microbes per 1000 c.c. of air was, 13, 42, and 80 respectively. These Dundee experiments make abundantly clear that in one-, two- and three-roomed houses, the impurity of the atmosphere must operate as an important factor in the causation of disease and death.

METHODS OF VENTILATION.

All schemes of ventilation are separable into two divisions, depending upon the motive power which originates them. In the one division, the motive power is found in the ordinary forces of nature, in the other, it takes the form of some kind of artificial mechanical power or aid. Ventilation produced by the forces of nature has been called *Natural* ventilation, that by mechanical or artificial power as *Artificial* or mechanical ventilation. The line of division must not, however, be pushed too closely, for reasons which are bound to emerge.

Natural Ventilation is produced by the operation of the following laws of gases, viz.:—

(*a*) By the law of diffusion of gases, established by Graham, viz.: that the relative velocities of diffusion of any two gases are inversely as the square root of their densities. The atmosphere, therefore, composed of a mechanical mixture of gases, being subject to this law, tends towards uniformity of composition;

(*b*) By the motion which is set up between two columns or bodies of air of different temperatures and pressures. The law of Charles is that a gas when heated, the pressure being constant, increases in volume to the same extent whatever the gas may be. The amount of expansion of a gas for each degree of increase of temperature is at once definite and determinable. One volume of a gas at 0° C., becomes 1 + ·003665, at 1°, or, in other words, increases by $\frac{1}{273}$ part of its volume; for every degree Fahrenheit above 32°, ·002, or $\frac{1}{491}$ part of its volume. Boyle's law for pressure is that the volume of a given weight of any gas is inversely as the pressure, where 760 millimetres of mercury is taken as the standard pressure.

(*c*) When a wind blows across a ventilating shaft or a chimney, or past a window, a partial vacuum,—in other words, a reduction of pressure—takes place in the shaft, chimney, or room, and a consequent increased upward or outward movement of air takes place. This action is called *perflation*.

Mechanical Ventilation.—All schemes of this class are also subject to division into two classes, viz.:—

(*a*) That in which the pure air is forced or propelled into the place to be ventilated under slight pressure, and hence has been denominated the *Propulsion* or *Plenum* method;

(*b*) That in which the foul air is extracted — the fresh air entering at prepared inlets—hence the name of *Extraction* or *Vacuum* Method.

Natural ventilation obtains in the average ordinary room in which the main available means of ventilation are (1) door, (2) window, (3) fire-place, not to speak of adventitious chinks in the flooring and walls of the apartment. With a live fire in the grate, the two former act as inlets, the latter as the outlet. A small grate will exhaust from the room-supply from 3 to 5 cubic feet per second, that is, from 10,800 to 18,000 cubic feet of air per hour, and an ordinary grate, from 5 to 8 cubic feet per second, or 18,000 to 28,000 feet. To supply these amounts air rushes in by window or windows and doorways, and by

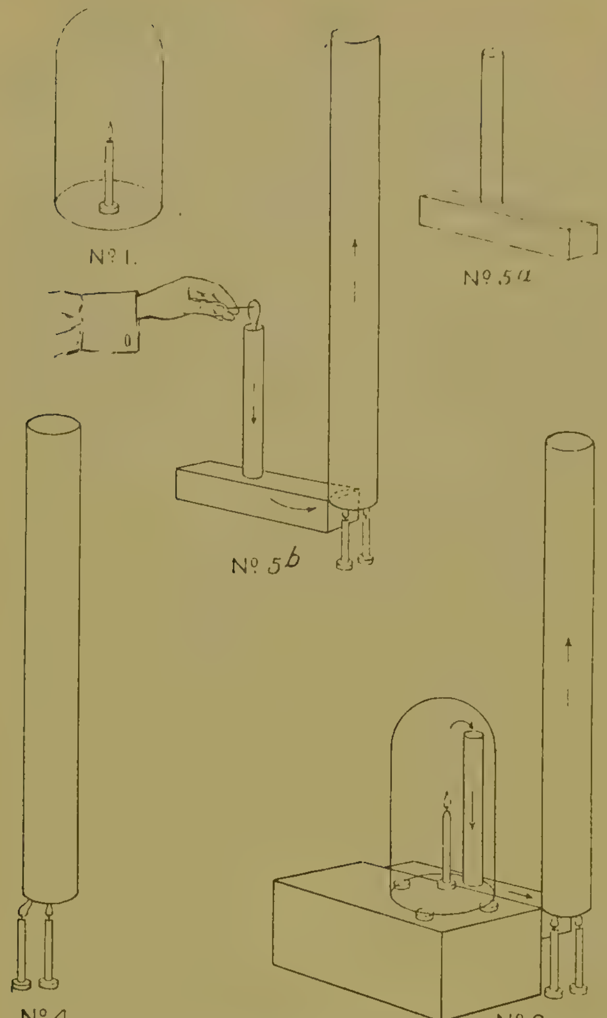


FIG. 114.

Apparatus for experimenting on the Principles of Ventilation. No. 1 is an ordinary thin-glass bell-jar and lit candle; No. 4, a cardboard funnel to show production of up-draught; No. 5*a*, a cardboard box with small cardboard funnel attached, both made air-tight; a small semi-lunar opening being made at one extremity of the box; No. 5*b* shows the effect upon a flame when Nos. 4 and 5*a* are fitted together; No. 6 shows these, with the addition of No. 1 slightly raised and standing on a box, fitted together. The last experiment illustrates the principles of Ventilation by Exhaustion or Extraction. *First Experiment.*—To prove that combustion or respiration will cease when air-supply is cut off. Under the bell-jar (No. 1) place a lighted candle. The light goes out when the air-supply of the bell-jar is used up. *Second Experiment.*—Place the bell-jar on a flat surface and raise it at three points by three pennies or thin pieces of cork. The lighted candle will again go out, because there is no movement of incoming air in the bell-jar. *Third Experiment.*—Place No. 4 and No. 5*a* in relation to one another as at No. 5*b*; place the candles as in No. 4; apply a piece of smoking brown paper, or a taper at the top of the smaller funnel, when it will be seen that the smoke is carried down the funnel through the box, in the direction of the arrow into the larger funnel. *Fourth Experiment.*—Place the pieces of apparatus already described as in No. 6. Light one or more candles under the bell-jar, and under the large funnel. The candles under the jar will burn brightly, because a movement of air is set up from beneath the bell-jar, down the smaller funnel, through the cardboard box and up the larger funnel; thus demonstrating that the foul air formed in the bell-jar is being constantly carried away.

any other available source. In the atmosphere of the ordinary room there are practically two strata of air, the lower reaching from the floor-level to the level of the artificial lights, the upper from the lights to the ceiling. The lower is the colder, because the entering cold air strikes a line between doorway and window and fireplace; the upper contains a column of relatively stagnant air, which is, usually, several degrees higher in temperature. Where there is no fire in the room the heat from the bodies of the occupants determines air-movements. According to the law of temperature of gases, the rate of velocity of inflow of air into the room is relative to the difference between the temperature of the outside and inside air; the greater the difference, the higher the velocity.

Methods by which Room-Ventilation may be Improved.—Different methods have been suggested whereby the entrance of fresh, and the exit of foul air may be rendered more uniform and more certain. These have been applied to (*a*) Windows, (*b*) Walls, and (*c*) Chimney of the room.

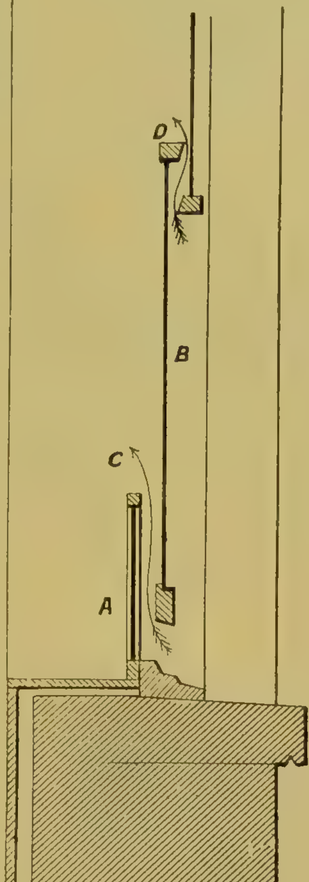


FIG. 115.—Mode of Ventilation by Window. *A*, glass-plate on inside of lower sash to prevent direct draught; *C*, direction of in-coming air from beneath open lower sash; *D*, raised part of lower sash, forming interspace at junction of sashes and direction of in-coming air.

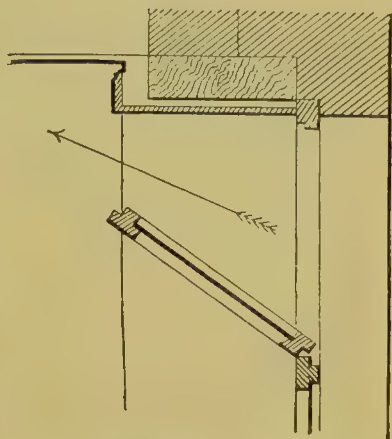


FIG. 116.—Window Ventilation by hinged frame in upper part of upper sash.

FIG. 117.—Mode of Wall Ventilation, by hinged perforated wooden brick. By opening or closing brick the amount of entering air can be regulated, while when closed, ventilation proceeds by the air-holes.

Window Ventilation.—The plan of Hinckes-Bird is very simple, and may be applied to any sash window. It consists in placing at the bottom of the window a block of wood of the exact width of the sash, and which may vary in thickness, on which the lower sash will rest. This causes the sashes to be separated at their junction, and enables air to pass from without inwards by the space created. (Figs. 115, 116.)

Another method is to affix a metal plate of zinc along the top of the window, which enables the upper sash to be pulled down sufficiently to produce an interspace at the junction of the sashes. Other methods, such as holes in the lower part of the upper sash, perforated panes, and double-glazed panes, where the outer pane has a bottom gap and the inner an upper gap, have been suggested, but they are objectionable in smoky atmospheres, because of "smuts" and dust collecting in the interspaces or openings. Double-sashed windows have also been tried. Better methods, however, are those by which Moore's louvre, or circular glass ventilator is fitted into the window-frame as a substitute for a pane.

FIG. 118.—Hatton's Hopper Window-Ventilator. The amount of in-coming air is regulated by the extent of opening the hopper, and is screened of soot particles by the fine copper gauze shown at top of figure. This soot is brushed away by the brush seen working against the gauze.

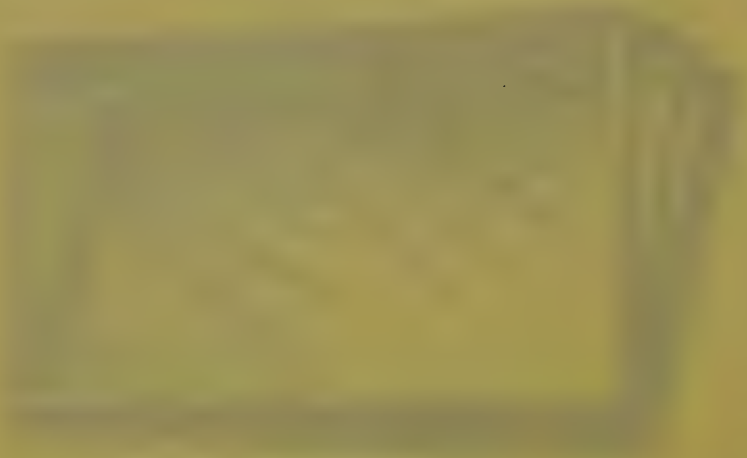
Another excellent method is to substitute for the upper half of the window, or a part of it if large, Hatton's hopper window-ventilator. This not only serves the purpose of a window-sash, but acts as a ventilator, and when so acting, not only prevents direct draught, but screens the air from particles.

Other methods are applicable to the sashes themselves. The following figures show some suggested by the writer. (Figs. 119 and 120.)

FIG. 119.

FIG. 120.

The above are photographs of four feet long working models. Fig. 119 may be made to act as an ordinary sash window, or the upper sash may be made to act as a hopper-ventilator, as shown in the figure, or the lower sash as a hinged window, as in Fig. 120. This is attained by means of sunk movable hinges in the side of window-frame. By means of these movements, differing amounts of ventilation, depending upon outside weather conditions,



may be obtained, and besides, the window may be wholly cleaned by a domestic from the interior of the apartment.

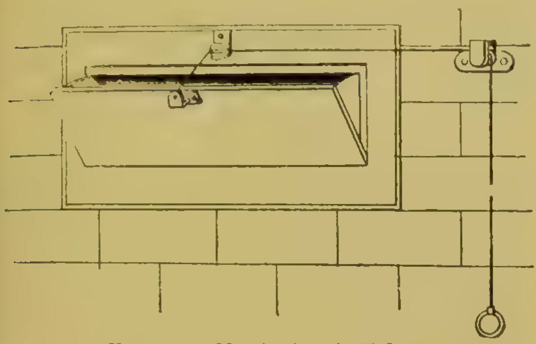


FIG. 121.—Sheringham's Valve.

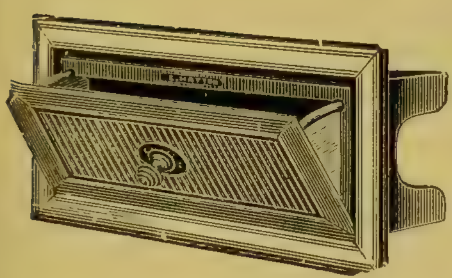


FIG. 122.—Hatton's Screen Valve. In this valve the air is screened on entering by means of fine copper gauze, and the gauze is kept clean of particulate matter by a brush which works on the gauze as the valve is opened and shut.

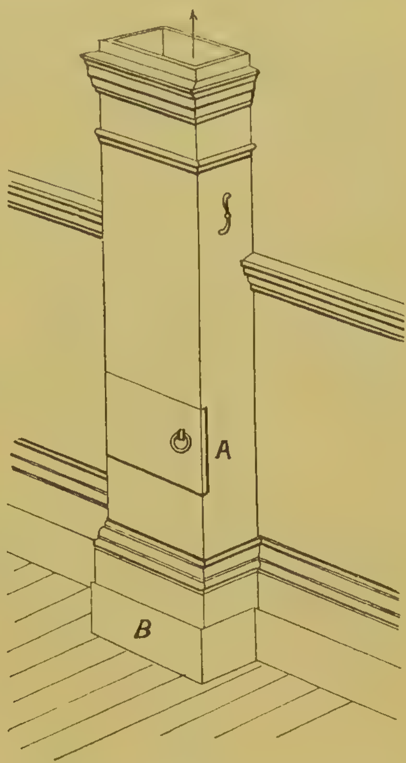


FIG. 123.—Tobin's Tube. By means of the opening at A, the tube may be periodically cleaned, and by means of the handle on the right side of the tube, which acts on a valve in the throat of the tube, the amount of in-coming air may be regulated.

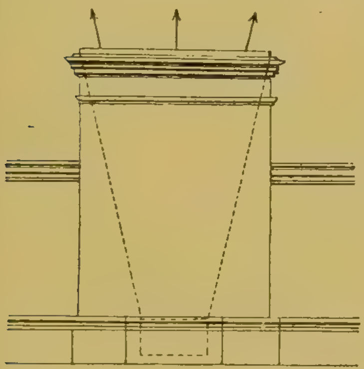


FIG. 124.—Another form of Tobin's Tube. This is shorter than Fig. 123, and is based on the principle that a current of air passing in a confined channel from a narrow point to a broader loses velocity. In this form of tube, although air may be entering rapidly at the contracted throat, it has lost all its harmful effects before it reaches the broader part at the top of the tube.

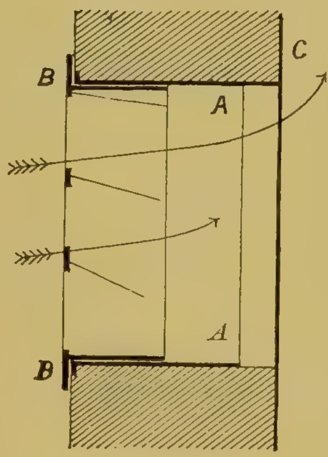


FIG. 125.—Chimney Valve. *B*, *B*, inner wall surface; *A*, *A*, valve-box; *C*, chimney. The arrows indicate direction of currents of air.

Wall Ventilation.—The special forms of ventilators applicable to outside walls of apartments are: (*a*) Sheringham's valve; (*b*) Hatton's

screen valve; (c) Tobin's tube. Placed in an outer wall, the one end communicates with the outer air, the other with the interior of the room. In the two former, the amount of entering air is regulated by the extent to which the hopper is opened; in the latter, by a screen in the throat of the tube. (Figs. 121, 122.)

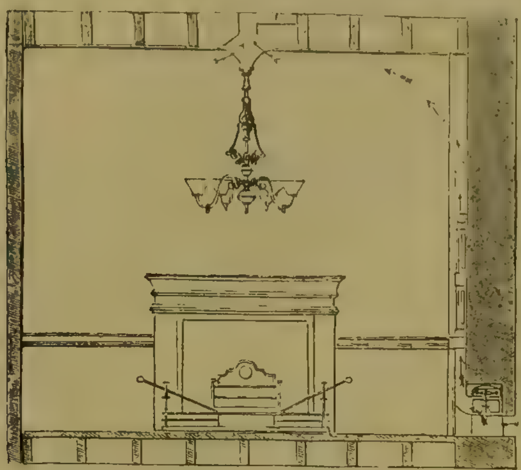


FIG. 126.—Ventilation of Room. Air enters at bottom of wall on right of figure, where it is washed by a rotatory spray of water, and passes into the room by a Tobin's Tube. The foul air is extracted by a hollow tube in the ceiling above the gasalier, the heat of the gas being the extractive motive power.

Tobin's tubes are of various forms. Their internal opening is placed from six to seven feet from the floor. Some possess a drawer, containing cotton wool, for the purpose of filtering the incoming air. (Figs. 123, 124.)

Chimney Ventilation.—Dr. Arnot, seeing the motive power which existed in the heated air of the chimney for extracting the foul air from the upper levels of a room, was the first to place in the wall of a room a valvular opening which connected the interior of the room with that of the chimney. (Fig. 125.) Owing, however, to the defective character of the fittings which permitted soot to be driven into the room by back-draughts in the flue, it was for a long time given up. But when workmanship improved and valves of mica were used, the chimney valve was revived. Those of Boyle and Buchan are in common use. The valves are so constructed that they only permit of air passing from room to chimney, consequently they act only as outlets. Such a ventilator, when well fitted, is a most efficient and useful outlet, and its position is just where an outlet is most needed.

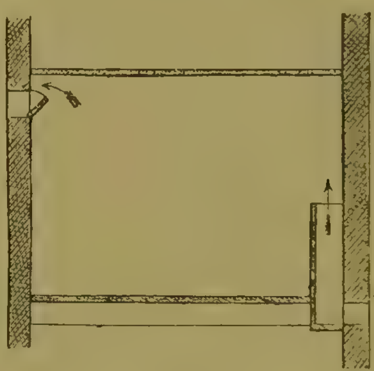


FIG. 127.—Tobin Tube and Sheringham Valve in position.

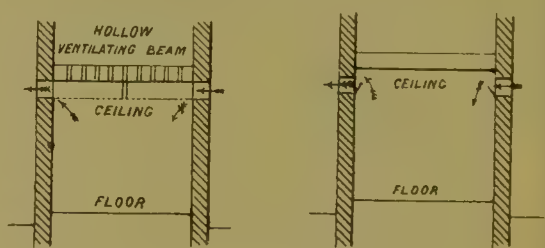


FIG. 128.—Other modes of ventilating rooms.

But methods have been devised, with some success, to utilise the spent heat of the fireplace itself as a means of supplying fresh warmed air to a room. By means of a special duct which either surrounds, or is in close proximity to, the source of heat, the ingoing fresh air is warmed, and is passed into the apartment either at the level of the ceiling, in the wall, or close to the fireplace. Of these

Galton's stove, George's calorigen, Bond's thermohydric stove, and the Canadian school stove may be considered as types. (Figs. 129, 130.)

For single-storeyed buildings, as churches, halls, schools, and other large buildings, or for apartments in the uppermost storey, roof ventilators have been devised, and the system has come to be known as *Roof-Ridge or Cowl Ventilation.* These roof-ridge appliances are either fixed or movable, and depend for their ventilating action upon the difference in pressure inside and outside a building, caused by the wind passing by and through them. (Fig. 131.) From the roof-ridge ventilator passes downward to the roof or ceiling of the building a shaft, which contains in its throat a valvular arrangement with silk valves, which acts only in one direction, viz. : toward the open air. The merits of this system of ventilation are (1) its comparatively cheap cost of installation; (2) its automatic action; and (3) its efficiency under

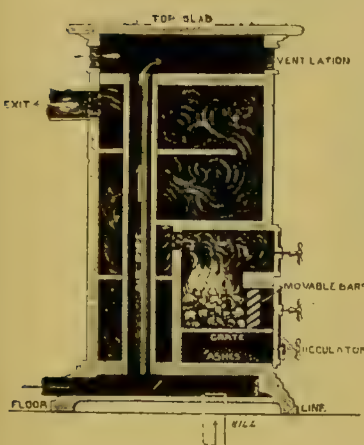


FIG. 129.—To illustrate one form of warming fresh air by a stove before admission to a building.

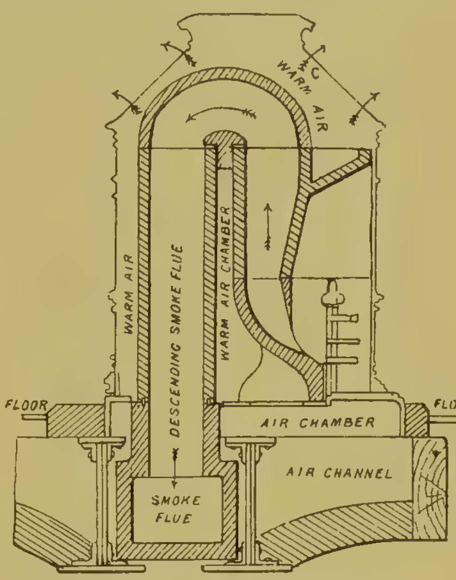


FIG. 130.—Another form of supplying fresh warmed air to a room. Section of Stove. (Rossie and Russell's Centre Grate.)

suitable circumstances. Since in this country, barring very exceptionally short intervals of time, the wind seldom moves with a less velocity than 20 miles an hour, the perflating action is likely to be sufficient, provided the capacity of the ventilating shaft is adequate for the place to be ventilated. The chief objections which may be urged against the system and the mode of installation are these: (1) its inconstant action; (2) derangement of the valves from clogging with dust, and thus permitting down-draughts; (3) the insufficient size of the ventilating shaft for the work it is expected to perform. The following figure shows the *modus operandi* of the ventilator and shaft. (Figs. 132, 133.) Such cowl arrangements have largely superseded the use of Mackinnel's tube, which is fitted on the roof-ridge like the foregoing, but differs from them in that it consists of two tubes, one inside the other, which pass downwards to the ceiling-level. The inner tube, which outside projects above the outer, and inside, below it, serves as

the outlet shaft for foul air. At the ceiling end of the inner tube is a broad flange or rim which is intended to deflect along the ceiling the cold air passing downward by the outer tube before it falls into the

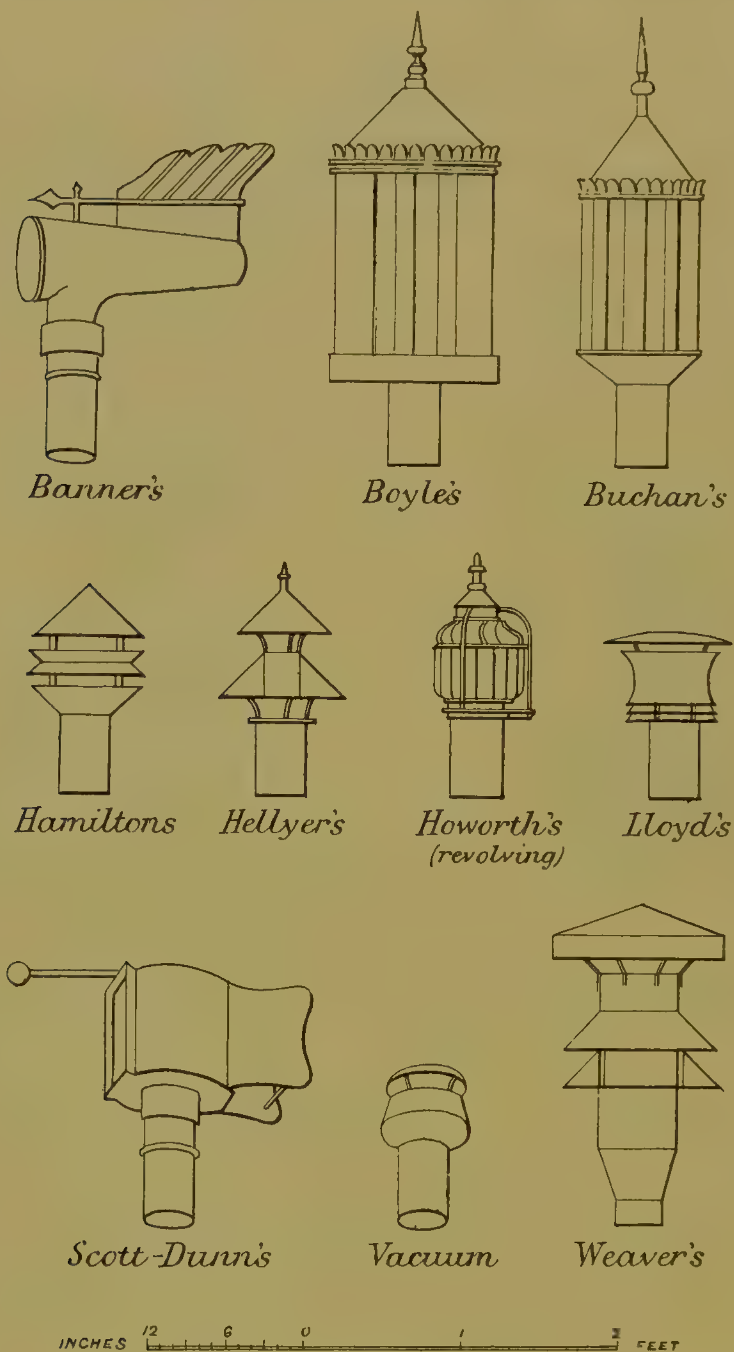


FIG. 131.—Forms of Ventilating Cowls.

apartment. In order that this apparatus should do the work intended, the sectional area of the space between the inner and outer tubes must be equal to that of the inner tube. In buildings such

roof-ridge apparatus may be made to act as an outlet ventilator when it is most required, by lighting a sun-light gas burner or Bunsen flame placed almost immediately beneath it.

From a consideration of these methods, it will be observed that ventilation may be effected by natural forces solely, or by these aided by artificial openings. It will further be perceived how unwise it would

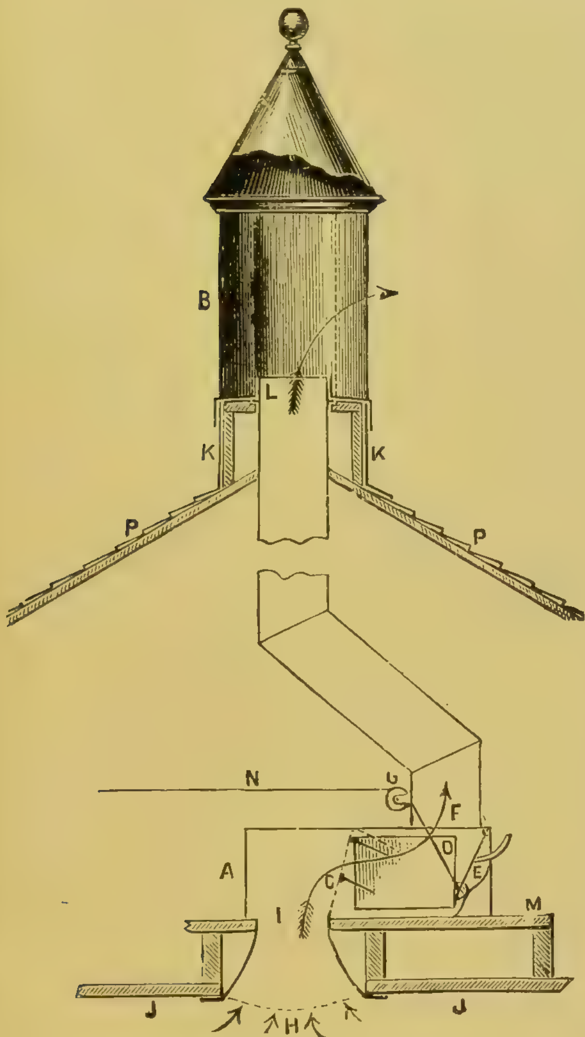


FIG. 132.—Buchan's Induced Current Fixed Ventilator. A, Valve-box; B, Fixed Ventilator; C, Silk Valve; L, Shaft; H, Grated opening in ceiling of building; J–J, Ceiling.

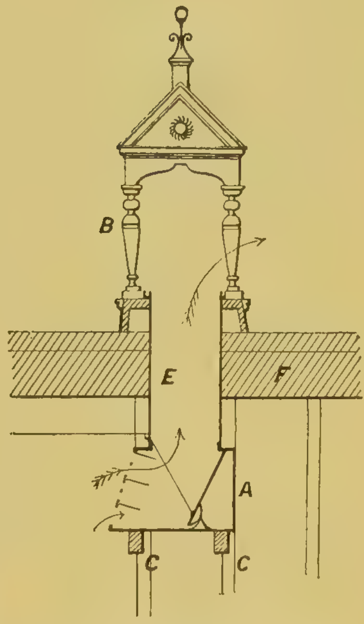


FIG. 133.—Simpler form of Roof-Ridge Ventilator. A, Valve-box; B, Fixed Ventilator; E, Air-shaft. Arrows indicate direction of air-current.

be to make the line of division between natural and artificial ventilation too arbitrary.

Mechanical Ventilation.—It may be said that ventilation of large buildings of complex design cannot be effected without recourse to some form of mechanical ventilation, and that in the employment of any such scheme warming of the air to be supplied must form an essential and integral part. When these are combined, and when the scheme is installed as part of the architect's or ventilator's

design during the construction of the building, adequate quantities of warmed air may be supplied. In populous places, whatever be the scheme employed, it is essential that the air to be supplied must be screened as free as possible of particulate matter. In the system of ventilation adopted in the chemical laboratory of University College, Dundee, the air is screened by being passed through jute cloth which is stretched on frames seventeen feet long by four in width. During seven weeks' operation, the amount of particulate matter arrested on the screens weighed 2½ pounds. Where such screening is not employed, much particulate matter is swept into the ventilating ducts and the apartments. Any one acquainted with a large library or museum, where in the ventilating apparatus screening of the air does not prevail, knows the huge amounts of impalpable fine dust which collects on books and objects of interest.

Schemes of mechanical ventilation are divisible into (1) those in which fresh air, washed and warmed, or warmed without washing and screened dry, is propelled into the building, and the foul air driven out by special ducts or channels; and (2) those in which the foul air is extracted, the fresh air entering by inlet channels to fill its place.

In the former system—*Plenum System*—the motive power acts at the beginning of the air circuit, and in the latter at its end. In the former, the motive power must be some form of mechanical force, such as a fan; in the latter, it may be a fire or a furnace in connection with a tall shaft, or a fan. Much has been written of the respective merits of both systems. From careful observations of both systems during some years, we believe efficiency to be on the side of the propulsion or plenum system, because of the reliability and steadiness of its action. In the plenum system originated by Key, the air is first washed and screened, is warmed, and is then propelled into the various rooms of the building. The washing is effected by causing the air to pass through a closely woven screen, composed of copper wire and fibre, which is constantly kept trickling wet from a trough at its upper edge, the water in which is kept from freezing in winter by a steam-coil; the heating by coils of steam-piping behind the screen, and by subsidiary coils in the basement ducts; and the propulsive power by a large fan. In order to make the system effective, the doors to each apartment must be doubled, the windows kept closed, and there must be no chimneys in the rooms. Of both this and the extraction system it may indeed be said, that the nearer the building to be ventilated is kept like a closed box with only two sets of openings, the more efficient is the ventilation. In the plenum system, the warmed air enters each apartment near the ceiling-level, and after it has served the needs of the occupants, the fouled air passes out by outlets placed at or near the floor-level. This it does by virtue of the measure of pressure with which it is propelled. This system is in operation in various large buildings in Glasgow, in the Birmingham General Infirmary, and elsewhere. (Fig. 134.)

The advantage of washing the air free of particulate matter is seen especially in foggy weather; whereas outside the building the fog

may be so dense that objects a few yards off cannot be descried, inside, the atmosphere is perfectly clear. Not only so, but bacteriological examination of the air of buildings so treated abundantly shows that micro-organisms also are arrested in the process of air-washing, judging by the great difference in numbers of those in the inside and outside air respectively.

In the Extraction or Vacuum system, the extracting power is either a furnace connected with a tall flue, steam jets, steam-, or hot-water coils placed in the extraction flue, or a fan operated by a gas-engine, or by electricity. In the House of Commons, ventilation is

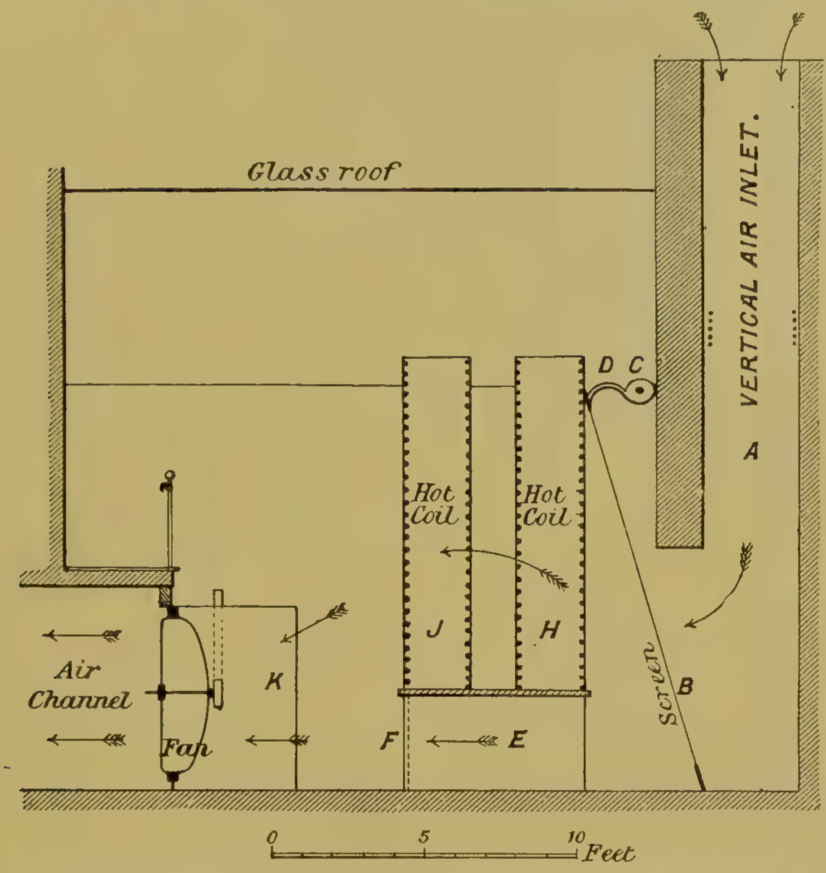


FIG. 134.—Working parts of Plenum System of Ventilation by which the air is screened, washed, warmed, and propelled into the building to be ventilated.

accomplished by the first mode, aided by propulsion. The incoming air is forced by fans along ducts to the basement, where it is warmed when necessary by being passed over steam-coils, the heat being regulated by covering and uncovering certain of the coils with woollen cloths. The warmed air then passes up shafts into the space below the floor of the House, and after being fouled, passes through the perforated glass ceiling, and thence by ducts to the basement of the clock-tower, where by the action of a furnace it is driven up the shaft or flue. (Fig. 135.)

Glover Lyon has suggested and devised a method of ventilation

devised by Cadett and himself in which the principles of both plenum and vacuum systems are utilised, by which he affirms that the air in rooms is maintained at nearly atmospheric pressure, the need for keeping rooms air-tight is avoided, and the sensation of stuffiness of air removed.

The points to be noted in connection with any mechanical scheme, he urges, are these: (1) That air entering a room in a given direction has a tendency by

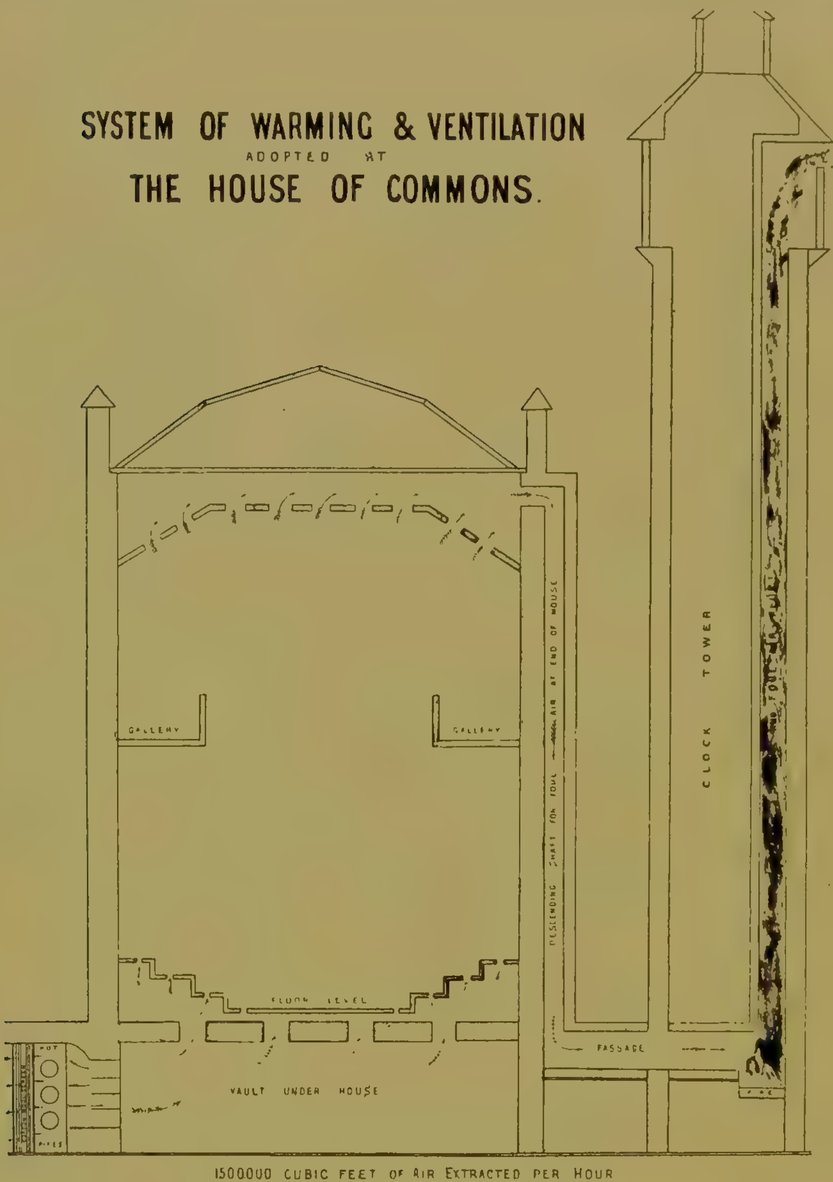


FIG. 135.

reason of its momentum to pass in the same direction—that is the impulse of inlet; (2) that air flowing in a room seeks the channels of least resistance—that is, toward free apertures or outlets—the impulse of outlet; (3) that air introduced into an occupied room is heavier than the existent air, and hence tends to fall—the internal fall; (4) that vitiated, warmed air tends to diffuse itself equally in an occupied room—internal diffusion; and (5) that vitiated, warmed

air tends to rise—internal ascent. Mechanical ventilation must depend upon the first two factors therefore, viz.: impulse of inlet, and impulse of outlet; and the more active these impulses, the less opportunity is there for the other factors to operate. Lyon characterises Key's system and that of Sturtevant, which are plenum schemes, as schemes merely for the dilution of foul air, and the extraction system as a failure, in that it causes, in order to be effective, intolerable draughts. His scheme he declares to be a compromise between these, and is intended to effect the convection of fresh air as directly as possible to the occupants of a room and the extraction of the vitiated air from the highest parts of the room which, he avers, are the foulest. In order to ensure the efficiency of the scheme, large inlets and outlets are required, the latter of which should be well distributed over the room-wall, so as to prevent "short-circuits" of air from inlet to outlet. In the scheme, the fresh air is admitted into the room by a conduit which is placed just above or below the floor near the wall. A tapering longitudinal slot is made along the top of this conduit, and baffle-plates are placed across the slot. It is contended that when air under velocity is forced into the end of the conduit where the slot is widest, when it reaches the narrowest part of the slot, it will be converted into an even stream of air which

FIG. 136.—Davidson's Scirocco Patent Fan. It is claimed that owing to the propeller-like shape of its blades a larger amount of air per equal number of revolutions is propelled than by fans of different shape.

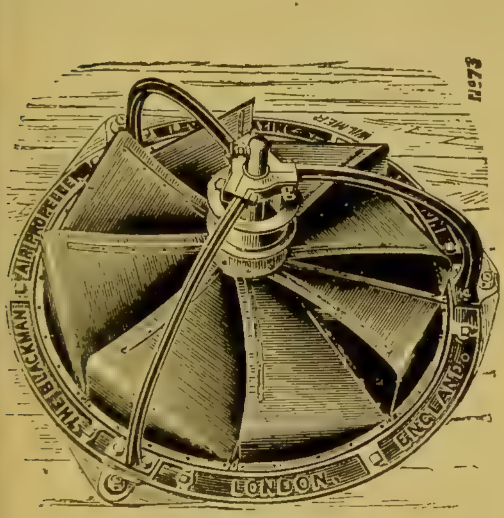


FIG. 137.—The Blackman Fan.

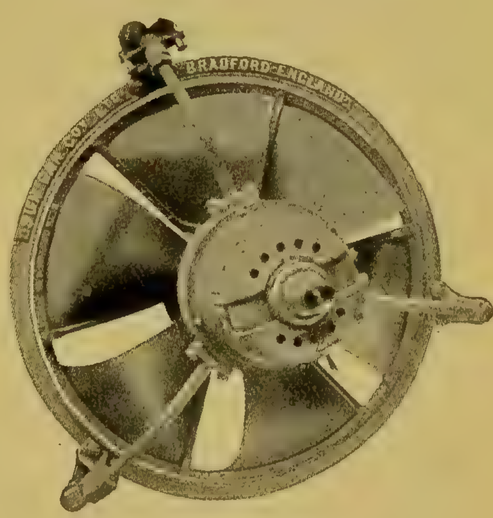


FIG. 138.—The Sun Fan.

will flow up the wall, since its momentum is changed into pressure, by reason of the baffle-plates and narrowed slot. If, then, a screen of wire gauze is placed above the slot and made to reach from floor to ceiling, the sheet of air flowing between the wall and the screen will be subdivided into a volume of air issuing evenly from the screen. The incoming air may be screened, washed, and warmed as in the plenum method if necessary. At the outlets, a similar conduit

is used, but the arrangement of the slot is reversed; that is, the widest part of the slot is at the room end of the conduit. This system, which has not yet been applied to the ventilation of occupied rooms, is to be worked in such by means of perforated panels set in the room walls as outlets and inlets, and at a level corresponding to about the middle three-quarters of the wall, having a dado below them and a frieze above. This may be one of the many schemes, more or less elaborate, which are established on sufficiently well-founded bases to give theoretically excellent results, but which are either impracticable or break down when practically applied.

The ventilation of mines is accomplished by extraction. In mines over a certain size there must be two shafts. Between these are the workings, which are so partitioned that the fresh air from the

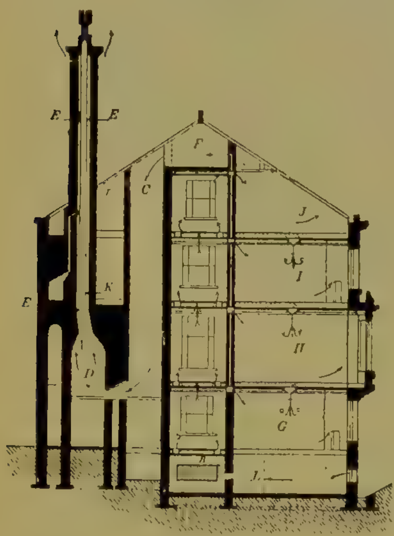


FIG. 139.—Drysdale and Hayward's combined system of Heating and Ventilation. The incoming fresh air is warmed in the basement, and is passed through the different rooms by inlet channels. By outlet openings the foul air passes from the rooms, etc., and these converge in the chamber F in the roof, whence the foul air is extracted by the extracting force of the heat of the kitchen fire by means of an air-shaft which encircles the smoke-flue.

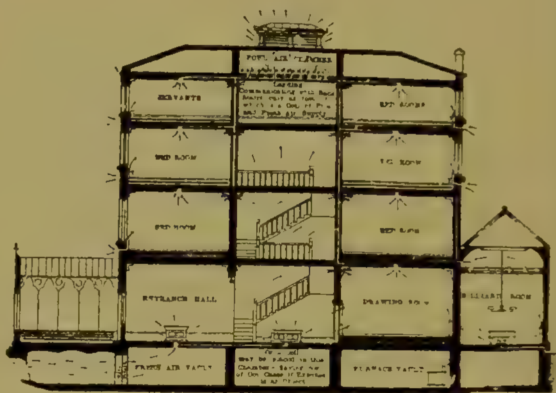


FIG. 140.—Renton Gibb's method of Heating and Ventilation. The central hall and stairway forms a reservoir of fresh, warmed air from which the rooms on the different landings are supplied. By means of extraction shafts from each room, the foul air is conveyed to a foul-air chamber in the roof, whence by means of a ventilating turret it is passed into the open air.

one shaft must pass through them before the air, fouled in its course, passes out by the other. In the outlet or upcast shaft the motive power is either a fire or a fan.

This extraction principle, besides, has been found of the greatest service as applied to the working-benches of certain occupations in which the workers are exposed to danger to health or life, either from the nature of the material worked with, or from particulate matter of a microbic character, as the anthrax bacillus in wool- and hair-sorting. By means of openings connected with a powerful extracting current, dust and particulate matter are drawn away from the workman into the extract shaft. In such operations as these, air propellers, blowers, and fans perform most useful service. They can be used with much advantage, moreover, as extractors of foul air from large rooms or buildings, and when they can be had

to act almost noiselessly, perform excellent service. Small fans may be actuated by water-power or electricity, larger ones, by a gas-engine or by electricity. (Figs. 141, 142.)

Mode of Testing practically Schemes of Ventilation.—There are three special branches into which an investigation into the efficiency of any large scheme of ventilation divides itself, viz. :—

I. The cubic space to be filled with fresh air, and the number of times per hour the air of the said space must be changed with reference to the number of occupants at any given time.

II. The efficiency of the mechanism by which the air-movement is to be effected.

III. Tests of the efficiency by physical and chemical methods.

1. The Cubic Space of the Building or Room to be ventilated.

In ascertaining the cubic contents of any confined empty space of the simplest kind, the multiplication of its length, breadth, and height in feet will give its amount in cubic feet. But in irregularly shaped rooms, special measurements must be made—that is to say, the cubic space may be estimated by a series of measurements for irregular spaces—the sum of which is the total cubic contents of the space. The following data will adapt themselves to any shape of room :—

Superficial Space.

- Area of Circle $= D^2 \times 0{\cdot}7854$.
- Circumference of Circle $= D \times 3{\cdot}1416$.
- Area of Ellipse = Product of both diameters $\times\ 0{\cdot}7854$.
- Circumference of Ellipse = Half the sum of both diameters $\times\ 3{\cdot}1416$.
- Area of Segment of Circle = $(\text{Chord} \times \text{Height} \times \frac{2}{3}) + \frac{\text{Height}^3}{2\ \text{Ch.}}$
- Area of a Square = The square of one of the sides.
- Area of Rectangle = The product of two of the adjacent sides.
- Area of Triangle = Base $\times$ Half the height.
- Area of a Parallelogram = Bisect into two triangles by a diagonal, and estimate the sum of the areas of the two triangles.

Cubic Space.

- Cubic Capacity of Cube = length $\times$ breadth $\times$ height.
- ,, ,, Solid Triangle = area $\times$ height.
- ,, ,, Cylinder = area of circular base $\times$ height.
- ,, ,, Cone = area of circular base $\times \frac{1}{3}$ height.
- ,, ,, Dome = area of circular base $\times \frac{2}{3}$ height.
- ,, ,, Sphere = diameter$^3 \times 0{\cdot}5236$.

In one or other or more than one of these ways, the *gross* cubic contents of any space may be estimated. After deduction of the cubic contents of solid or closed bodies, as furniture, etc., the *net* cubic contents are arrived at. For a bed it is customary to allow ten, and for an adult three cubic feet.

2. The next step is to ascertain the number of occupants—the average, minimum, and maximum numbers—in the case of a hall, church, or school. For a mixed adult audience, an allowance of 3000 cubic feet of air per hour is the ideal to be aimed at ; for children of mixed ages in schools, 2000–2500 cubic feet per hour. These allowances per head per hour multiplied by the number of occupants gives the total number of cubic feet of air to be supplied per hour.

Examine next for inlets and outlets. The superficial area of inlets and outlets, where the air is warmed, should not be less than 48 square inches per person. This will allow of the air being sent in at

a velocity of about 2½ feet per second. But these may be enlarged up to 70 or 80 square inches per head—the air being warmed—where the net cubic space for the total number of individuals is less than the ideal amount. The sum of the superficial areas of inlets or outlets divided by the number of occupants will give the inlet or outlet area per individual.

The rate of velocity of the incoming air at the inlets must then be tested by the anemometer. The instrument should be placed, not in the centre of the opening, but at a point about ⅗ths of the diameter from its side, as this point best gives the mean velocity. The instrument having been maintained for one minute in this position, the

FIG. 141 illustrates the Ventilation and Purification of Air of a Smith's Shop by means of the "Scirocco" Fan. The position of the fan is indicated on the left of the figure, at the end of the exhaust air-shaft which is seen to pass from the right to the left of the figure, and into which passes the smoke which, otherwise, would pollute the atmosphere of the workshop.

number of revolutions registered, minus the correction for the individual instrument—supplied by the makers—will give the linear velocity in that time; and the linear velocity multiplied into the sectional area of the opening will give the number of cubic feet supplied per minute. It is a good plan to apply the anemometric test to a series of inlets in various parts of the room. This test, in our opinion, is the most important of all from the practical point of view, as it demonstrates the *actual* amount of air which is being supplied to the room. The temperature of the incoming air, of the room itself at various points, and at various outlets, ought also to be taken. The supply of air will be found to be most constant in the *plenum* system, since the motive power may be kept constantly doing a definite amount of work. By comparison, therefore, of the figures of the

actual supply of air as estimated, with the amount required or desiderated, the efficiency of the ventilation machinery may be tested. In testing under the vacuum method, the same general principles as the foregoing apply. It has been already stated that the rate of movement of air depends upon the difference in temperature between the outside air and that of the extracting shaft, chimney, or flue. Where the motive power is a fan working in or at the bottom of the shaft, the rate will depend upon the sectional area of the fan and its velocity or number of revolutions per minute. In a heated chimney, flue, or shaft, whether the source of heat be a furnace, coils of steam piping,

FIG. 142.—Workshop, the air of which is kept free of the particles from the grinding machines by means of the exhaust shafts seen immediately beneath each wheel.

or a steam nozzle, the rate of movement depends upon the action of two well-known physical laws, viz. :—

1. That the velocity of a falling body in feet per second is equal (nearly) to 8 times—in fact, 8·02 times—the square root of the distance or height through which it has fallen.

$$V=\sqrt{2gH}$$

where v = velocity

g = gravity = 32·18, the number of feet fallen in one second.

H = height or distance.

$\therefore\ \sqrt{2g}=\sqrt{64{\cdot}36}=8{\cdot}02$ nearly, or $\underline{8}$.

2. That fluids flow through an aperture with a velocity equal to that of a body falling through a height equal to the difference in height of the columns of air on either side.

The formula now becomes: $V=8\sqrt{H-h}$.

In applying these laws, which are known as *Montgolfier's Theorem or Rule*, to the movement of air, account must be taken of the different densities of air at different temperatures due to its expansion by heat. H is taken to equal the height of the atmosphere, which may be considered to be a column of air of uniform density and five miles in height, and which, at sea-level, supports a column of mercury of 760 millimetres in height. If, then, such a column of air were to rush into a vacuum, it would do so with a velocity equal to that of a solid body falling through a distance of five miles, or 26,400 feet, viz., of about 1300 feet per second:—

$$\sqrt{2gH}=\sqrt{2\times 32{\cdot}18\times 26,400}=\sqrt{1303} \text{ feet per second.}$$

But if the same column of air were to pass into a room the air of which is not a vacuum but which has less pressure than itself, then its velocity will be equal only to that attained by a solid body falling through a height measured by the difference of the pressure inside and outside, as estimated from the difference of the temperatures. Where heating takes place in a flue or chimney open only at both ends, the expansion of the air can only take place by the confined column of air becoming longer. This increase of length corresponds to h. We have seen that one volume of air expands $\frac{1}{491}$ part for each degree Fahrenheit it is raised in temperature above 32°. The co-efficient for this amount of expansion is ·002036, or, shortly, ·002. The difference in pressure, therefore, is ascertained by multiplying the difference in temperature of the outside and inside air by this co-efficient of expansion, viz., ·002.

From these data, then, the following formula is constructed:—

$$V=\sqrt{2gHa(t-t')}.$$

Where V = velocity of ascending air in feet per second;
H = Height of shaft or flue in feet;
t = Temperature of air in shaft;
t' = Temperature of outside air;
a = co-efficient of expansion of air = ·002 per degree F.;
g = 32·18 = number of feet fallen by a body in first second.

Example.—A ventilating shaft, fifty feet in height, straight and circular in shape, has a sectional area of three feet; the temperature in the shaft is 65° F., that of the outside air being 45° F.; it is required to find the quantity of air passing out per hour.

$$V=\sqrt{2gHa(t-t')}$$
$$V=\sqrt{2\times 32{\cdot}18\times 50\times(65-45){\cdot}002}$$
$$V=113 \text{ feet per second of linear velocity.}$$

The linear velocity multiplied by the sectional area of the shaft will give the amount of air in cubic feet discharged per second. The sectional area in this case is 3 feet.

Therefore $113\times 3\times 60\times 60=1,220,400$ cubic feet per hour.

It must be noted, however, that the *calculated* or *theoretical* linear velocity is not realised in experience, because of friction in the shaft; hence the *actual* velocity is diminished according to the amount of friction which the outgoing air experiences, and this depends upon the character of the shaft, in respect whether it be circular or square, straight or curved, or angular, and whether its interior be smooth or rough. Allowance must, therefore, be made in practice for friction, which allowance may vary from ¼ to ½ the linear velocity. This, however, may be checked by anemometric observations.

Based on these laws, du Chaumont has proposed two formulas: (1) for calculating the total size of outlets and inlets required to deliver a given number of cubic feet of air per hour.

$$\frac{D}{100\sqrt{H(t-t')\times{\cdot}002}}=\phi.$$

(2) To determine the delivery per hour, the size of the inlet opening or openings being known.

$$200\sqrt{H(t-t')} \times \cdot 002\phi = D.$$

Where D = Delivery of air in cubic feet per hour.
H = Height of shaft in feet.
t = Temperature inside shaft.
t' = Temperature of outside air.
ϕ = Sectional area of inlet, or outlet, in square inches.
200 = A constant, obtained by dividing the number of seconds in one hour by the number of square inches in a square foot, and multiplying the product by the square root of twice the gravity:—

$$\text{thus: } \frac{3600}{144} = 25 \times (\sqrt{32\cdot 2 \times 2}) = 8 = 200.$$

3. The third branch of the inquiry consists in the application of physical and chemical tests to the air of the place. The best physical tests to employ for rooms occupied for an hour or two consecutively—as for example, a schoolroom—is the estimation of watery vapour, and temperature. In imperfectly ventilated rooms there is a definite increase of watery vapour, and the temperature is also raised some degrees. Such an atmosphere becomes oppressive, and, without any examination as to efficiency of action, the particular system of ventilation in use is liable to be blamed as the cause. The element in the atmosphere of a room which lends itself most easily to chemical analysis is the Carbonic Acid gas, and this may be taken as a comparatively accurate measurement of the amount of organic matter in the same air. The researches of Carnelly and others[1] demonstrate this. To estimate the amount of CO_2 present in air, different methods may be employed, as those of Angus Smith, Lunge-Zeckendorff, Wolpert, Hesse, and Pettenkofer, the first three of which, however, are only approximate methods.

Approximate Methods.—1. The method of Angus Smith requires a series of stoppered bottles, measuring respectively 20, 10½, 8, and 6½ ounces. The reagent used is lime-water or baryta-water, and the amount used at each experiment is half an ounce. The test is employed as follows: Into the 10½ ounce bottle is put the necessary amount of lime-water, and the bottle stoppered and shaken freely for about one minute. Should the clear reagent have now become turbid, the sample of air contains more than ·06 per cent. of CO_2; if no turbidity result, it does not contain more than this proportion. By using the other-sized bottles, the quantity greater than ·06 per cent. may be approximately arrived at by observing in what size of bottle, with the like quantity of reagent, turbidity appears.

Size of bottle in ounces.	No Precipitate CO_2 per cent.
20½	·03
10½	·06
8	·08
6½	·10

It will be obvious from the health point of view, that little concern will attach to percentages of CO_2 less than ·06.

2. *The Lunge-Zeckendorff Method* requires care on the part of the operator so that the necessary conditions for accuracy may be fulfilled; otherwise, the method is simple. The apparatus consists (1) of a bottle of known cubic capacity, stoppered by an india-rubber cork perforated in two holes through

[1] *Roy. Soc. Trans.*, vol. 178, 1888.

which pass two glass tubes, one of which is connected with (2) a rubber ball of definite capacity, by means of a rubber tubing. The reagent used is a $\frac{N}{500}$ or 500th normal standard solution of carbonate of soda (·02 gramme per litre), coloured pink with phenolphthalein as an indicator. It is better to make a $\frac{N}{10}$ solution, viz.:—5·3 grammes dry Na_2CO_2 per one litre of water after addition of 1 gramme of indicator dissolved in alchol. For use, 2 c.c. of this solution are diluted to 100 c.c. with distilled water, of which 10 c.c. are used for each determination. To use the apparatus 10 c.c. of the $\frac{N}{500}$ solution are put into the bottle with a pipette, the attachments are fixed, and the rubber ball is compressed and released alternately so as slowly to force the air through the solution in the bottle, the contents being agitated after each ballful, until the pink colour disappears. The disappearance of the colour shows that the alkaline carbonate has been converted into the acid carbonate by the CO_2 added from the air, as the indicator-colour is discharged in acid solutions. Reference to a table, which is supplied with the apparatus, shows, from the number of ballfuls used, the percentage amount of CO_2 in the air examined. Provided that care is exercised in the filling and emptying the rubber ball in passing the air through slowly and regularly, and in agitating the reagent, our experience of the method is that it is a fairly reliable approximate guide to the atmospheric CO_2 present.

3. *Wolpert's Method.*—The *rationale* of this method is exactly the same as the preceding, but the apparatus used is different. The apparatus consists of a glass cylinder marked in ½ and 1 c.c. into which is fitted a piston, the lower extremity of which is made of india-rubber to cause it to fit exactly. The piston-shaft is hollow. The upper extremity is fitted with an india-rubber cap, which is removable. The shaft of the piston passes through a metal cap which is adjusted to the top of the glass cylinder. The reagent used is a standardised solution of pure dry sodium carbonate, containing phenolphthalein as an indicator, in dilute alcohol and water, 1 c.c. of which contains ·074 mgrm. of the soda and ·016 gramme of phenolphthalein. *Process.*—In order to fill the glass cylinder with air to be examined it is only necessary to work the piston up and down three or four times. To estimate the contained CO_2 remove the piston, put into the cylinder 2 c.c. of above coloured alkaline solution, replace cylinder, push it down to the 10 c.c. mark, put cap on piston, and shake cylinder and contents; if colour be not discharged, pull out piston to 20 c.c. and after replacing cap on piston, again shake. By continuing this process until the solution becomes decolorised, the amount of CO_2 present is calculated thus: From number of c.c. of air used, deduct 2 c.c. for space occupied by solution and divide 31·3 by the remaining figure. The figure 31·3 represents the number of c.c. of air containing 1 part CO_2 per 1000 of air which is necessary to decolorise 2 c.c. of the above coloured alkaline solution. In the more modern instruments, by means of a graduated scale engraved on the apparatus the parts per 1000 are supplied, and the calculation, therefore, rendered unnecessary.

Exact Methods.—(1) Pettenkofer's method is, however, one of the most exact.

It may be carried out in one of two ways, (*a*) either by the use of large glass jars, such as very large Winchester quarts, the cubic capacity of which in c.c. is known and marked thereon; or (*b*) by the use of air-tubes—Pettenkofer's latest mode—connected with an aspirating apparatus of known capacity.

The following apparatus is required:—

(1) Glass-jars, fitted with india-rubber stoppers, holding about 4000 to 6000 c.c.; or two Pettenkofer tubes.

(2) Burette, graduated in c.c. and tenths, to hold 100 c.c.

(3) Pipettes to hold 30, 50, and 60 c.c. respectively;

Chemical Solutions required:—

1. A clear solution of Baryta Water, made up of 4½ grammes of Barium hydrate and ¼ gramme of Barium chloride, per litre of distilled water; Barium chloride is added because the barium hydrate usually contains small proportions of Ba_2CO_3 and NaHO or KHO. The chloride converts the NaHO into NaCl and the $BaCl_2$ into the hydrated oxide, thus: $2NaHO + BaCl_2 = 2NaCl + Ba(OH)_2$. Without the addition of the chloride, exact titration is prevented.

ESTIMATION OF ATMOSPHERIC CARBON DIOXIDE.

BY

JAMES WALKER.

From the Transactions of the Chemical Society, 1900. Vol. 77.

C.—*Estimation of Atmospheric Carbon Dioxide.*

By JAMES WALKER.

WHEN atmospheric carbon dioxide is estimated by means of Pettenkofer's method in its ordinary form, the results are often irregular and almost invariably too high from absorption of carbon dioxide from expired air during the process of titration. Many modifications have been proposed for avoiding this and other sources of error. For an account of these and for valuable accurate original observations, reference may be made to the memoirs of Blochmann (*Annalen*, 1887, **237**, 39) and of Letts and Blake (*Proc. Royal Dublin Soc.*, 1900, **9**, 107).

The following modification, which I have used for some time, can be worked without any special appliances, and gives results which have an accuracy of 0·1 part in 10,000 under ordinary circumstances, whilst permitting the analysis of air containing any quantity of carbon dioxide from 0 to 40 volumes in 10,000 without any alteration in the mode of working.

The solutions employed are decinormal hydrochloric acid which has been exactly standardised, and a clear solution of baryta, the strength of which relatively to the hydrochloric acid is accurately known. The baryta solution is most conveniently made about 0·02 normal, and is kept in a stock bottle with a 50 c.c. burette attached, as described in Ostwald's *Physicochemical Measurements*, pp. 88 and 250.

The bottle in which the sample is collected is a clean, dry Winchester quart, the capacity of which has been previously determined. This bottle may either be furnished with a rubber stopper and tubes as described below, or with its own ground glass stopper covered with a very thin film of a stiff grease. In the latter case, immediately before the determination is to take place, the glass stopper is rapidly exchanged in the open air for a rubber stopper through which pass two glass tubes, about 7 mm. in diameter. The longer tube reaches almost to the bottom of the bottle; the shorter tube ends internally flush with the stopper. Both tubes project externally about 2 inches, and are provided with stopcocks at slightly different levels so as to permit of convenient manipulation. There is permanently attached to the upper end of the longer tube a piece of rubber tubing 1 inch in

length which serves to connect it with the jet of the baryta burette. This jet is best constructed of barometer tubing very slightly tapered and cut off square at the end. Fifty c.c. of baryta solution, which will suffice for 40 vols. of carbon dioxide in 10,000 vols. of air, are slowly run in with both stopcocks open. The rubber is then detached from the jet and compressed by the fingers in order to force the baryta solution which may remain in the tube down below the level of the stopcock. Both stopcocks are then closed, and the bottle, which is allowed to lie on its side, is agitated from time to time.

While the absorption of the carbon dioxide is in progress, an asbestos filter is prepared. The best form to use is a Soxhlet cuprous oxide tube, which is fitted into a filtering flask of about 200 c.c. capacity by means of a rubber stopper. A very small quantity of asbestos well teased out is pressed down over the capillary portion of the tube, the filter pump is then turned on, and several fills of distilled water run through the tube. When the pump is running at full speed, the water should flow from the filter tube in a continuous stream, but should only drop slowly when the suction is slight. After a little practice has been acquired, the preparation of a satisfactory filter only occupies a few minutes.

If the bottle has been repeatedly agitated, the absorption of the carbon dioxide may be regarded as complete in 15 minutes, and the filtration may take place. Ten c.c. of hydrochloric acid solution are introduced into the empty filtering flask by means of a pipette which is always used for the same purpose; the filter tube is fitted in, and the flask, resting on the sole of a retort stand, is clamped firmly by the neck. The bottle is now clamped in an inverted position on the same retort stand about 8 inches above the top of the filtering tube. Into this there is fitted a rubber stopper, through which passes a short glass tube, connection with the shorter tube of the bottle being completed by means of a piece of rubber tubing $\frac{1}{8}$ inch in bore, $\frac{3}{8}$ in diameter, and about 8 inches in length. The filter pump is now turned on, and the stopcock of the shorter tube slowly opened. The barium carbonate remains on the asbestos, and the clear baryta solution which passes through is at once neutralised by the hydrochloric acid. When all the liquid has been filtered, the pump is allowed to act for a few moments so as to partially exhaust the bottle. The stopcock of the shorter tube is then closed.

Meanwhile 100 c.c. of distilled water, which always contains carbon dioxide in solution (compare Letts and Blake, *loc. cit.*, 125; Walker and Cormack, this vol., 8, 11), is neutralised by adding to it phenolphthalein, a little barium chloride solution, and then baryta solution until an incipient pink colour is produced. Into this prepared wash-water, contained in a small beaker, the end of the longer tube is

dipped, and the stopcock opened. The bottle being partially exhausted, water flows up the tube into the interior. When 20—30 c.c. have entered, the stopcock is closed. The bottle is then unclamped, and thoroughly rinsed by rotating and shaking while in a horizontal position. After the bottle is replaced in the clamp, the stopcock of the shorter tube is opened, and the wash-water allowed to filter into the flask. This process of washing is twice repeated. At the third washing, the prepared water is not in general turned pink when the bottle has been rinsed, showing that no baryta remains. Air is now admitted and the flask detached. The contents may be titrated with the standard baryta solution directly in the flask, but I have found it more convenient to transfer them to a porcelain casserole before titration. When the point of neutralisation is almost reached, the flask is washed out with a portion of the nearly neutralised liquid, and the neutralisation then completed.

The mode of calculation may best be seen from the following example.

Ten c.c. of decinormal hydrochloric acid required 50·80 c.c. of the baryta solution for neutralisation. One c.c. of baryta solution therefore corresponded to 0·2205 c.c. of CO_2 at N.T.P.

The capacity of the bottle used was 2650 c.c., and the temperature of collection 15°. Fifty c.c. of baryta were introduced into the bottle, so that the air remaining in the bottle was $2650 - 50 = 2600$ c.c. After absorption of the carbon dioxide, the baryta was filtered and washed into 10 c.c. of decinormal HCl, which then required 4·50 c.c. of baryta for complete neutralisation. There were thus used altogether $50{\cdot}00 + 4{\cdot}50 = 54{\cdot}50$ c.c. of baryta solution, 50·80 of which were neutralised by the hydrochloric acid, giving 3·70 as the remainder neutralised by the carbon dioxide contained in the air examined. For the proportion of carbon dioxide in the air we have then

$$\frac{3{\cdot}70 \times 0{\cdot}2205 \times 10540}{2600} = 3{\cdot}31 \text{ vols. } CO_2 \text{ in } 10{,}000 \text{ vols.},$$

10,540 being the volume occupied at 15° by 10,000 vols. air at 0°.

In order that a comparison of Pettenkofer's original process and the modified method may be effected, I give a few results in which both modes of analysis were adopted, the samples being collected simultaneously. For the Pettenkofer values I am indebted to Mr. John Foggie, who has had a very large experience of the method.

Pettenkofer's method.	Modified method.	Difference.
4·4	3·7	0·7
4·1	3·5	0·6
26·4	26·2	0·2

These numbers reproduce almost exactly the differences found by Haldane and Pembrey between the Pettenkofer bottle method and their own gravimetric method (*Phil. Mag.*, 1890, [v], 29, 306).

In order to test the modification directly, several blank experiments were made. The experimental bottle was filled with air perfectly free from carbon dioxide, and the whole process of estimation gone through exactly as above described. In three experiments, the quantities of carbon dioxide found were 0·09, 0·02, and 0·05 vol. in 10,000 vols. of air. Again, 1·89 c.c. of carbon dioxide measured at 19° and 761 mm., corresponding to 1·77 c.c. at N.T.P., were introduced into the vacuous bottle which was then filled with air free from carbon dioxide. The quantity of carbon dioxide found by analysis was 1·78 c.c. at N.T.P., the error being 0·04 vol. in 10,000 vols. of air.

It is thus apparent that the method under the above conditions gives results which have certainly an error amounting to less than 0·1 part in 10,000, whilst permitting estimations up to 40 vols. in 10,000. Greater accuracy could no doubt be obtained by using considerably more dilute solutions, but the range of the method would be thereby limited. It is possible, as Mr. Foggie showed in some special experiments, to work the process accurately in bottles of only 1 litre capacity, a great convenience when many samples have to be collected at a distance from the laboratory. In this case, it is expedient to use twentieth normal hydrochloric acid and hundredth normal baryta. The time occupied in the analysis of a sample is generally less than half an hour.

With respect to the action of baryta solution on glass or rubber, which has been proved by various experimenters to affect the titre of the solution, it may be said that the error due to this cause is negligible in the above mode of working, the time during which the baryta is in contact with the bottle being too short for appreciable action, at least in the case of bottles which have been previously used for the same purpose.

If, as sometimes happens when the air is collected in factories or workshops, the temperature of collection is greatly above the atmospheric or laboratory temperature, a correction must be made for the amount of carbon dioxide which enters with the atmospheric air when the pressure is adjusted by opening the bottle before analysis. This correction may easily be calculated on the assumption that the external air contains 3 vols. in 10,000, and only amounts to 0·1 vol. for 10° difference in temperature. The rapid substitution of the rubber stopper for the glass stopper does not appreciably affect the result, as the following example shows. Two samples were collected simultaneously, one bottle being provided with the rubber stopper and tubes, and the other with a glass stopper. The results of the analyses

were 13·00 and 12·93 respectively, the difference being 0·07 vol. in 10,000. I have also found that the samples may be safely left for 24 hours before analysis, whether a rubber or a glass stopper is used.

UNIVERSITY COLLEGE, DUNDEE.

RICHARD CLAY AND SONS, LIMITED, LONDON AND BUNGAY.

THE GLEBE,
PENSHURST,
KENT.

March 9th
1905

Dear Sir

On reading through your book on Medical Jurisprudence & Public Health I found the following 'errata' which you might like to know about.

(1) <u>page 532.</u>

"$400 + \frac{17}{4} + 36{,}000 = 37{,}000$ = the Engd popn of 1885"

should read.

$400 \times \frac{17}{4} + 36{,}000 = 37{,}000$

(2)

Page 538.

Therefore the factor for correction for age and sex for Huddersfield is $\frac{19 \cdot 15}{16 \cdot 47} \times 1 \cdot 1627$.

Should read:-

$$\frac{19 \cdot 15}{16 \cdot 47} = 1 \cdot 1627.$$

Hoping that these errors have not been previously pointed out & that I have not troubled you for nothing

I remain yrs truly

Philip. S. Tillard.

2. Standard solution of Oxalic acid, made by dissolving 1·404 grammes of the pure crystals in one litre of distilled water, and of which 1 c.c. = ·25 vol. of CO_2.

$$\text{Thus: Oxalic Acid} = \frac{C_2O_4H_2 + 2H_2O}{12 \times 2 + 16 \times 4 + 1 \times 2 + 2 \times 2 + 16 \times 2 = 126}$$

$$\text{Carbonic Acid} = \frac{CO_2}{12 + 16 \times 2 = 44}$$

One molecule $Ba(HO)_2$ consumes, or takes up, 1 molecule oxalic acid to form Barium oxalate ($BaC_2O_4 + 4H_2O$). One litre of CO_2 at normal temperature and pressure weighs 1·971 grains ($\cdot 0896 \times \frac{44}{2} = 1{\cdot}971$) and a quarter of a litre, $1{\cdot}971 \div 4 \doteq \cdot 492$ gramme. Therefore the amount of oxalic acid to be used is $\frac{126 \times 0{\cdot}492}{44} = 1{\cdot}404$ grammes, of which 1 c.c. is equivalent to 0·25 vol. of CO_2.

3. Saturated solution of phenolphthalein, as an indicator.

Rationale of Process.—The test depends upon the relative causticity or alkalinity of the Baryta solution before and after its exposure to the air which contains the CO_2, the amount of difference in alkalinity being the measure of the amount of CO_2 present.

Modus operandi.—The jar to be used is filled with water, and is emptied and allowed to drip dry in the place the air of which is to be examined. Thereafter, 60 c.c. of the Baryta water are poured into the jar, the rubber stopper tightly fixed, and the bottle and contents are periodically agitated during the next ½ to 1 hour. Meanwhile, 30 c.c. of the Baryta water, to which have been added two drops of the phenolphthalein solution, coloured pinkish-red thereby, are titrated in a practically closed flask with standard oxalic acid from a burette. The acid is allowed to run in regularly, with constant agitation of the flask, until the pink colour is discharged; the number of c.c. of acid used is noted. A second more carefully performed test is then made in the same way, but special care is given to the *end-reaction.* Then the quantity of acid in c.c. used in neutralising the 30 c.c. of Baryta water is put down. At the end of the hour, the Baryta water in the air-jar is poured out by means of a glass funnel into a 100-c.c. glass-stoppered bottle, is there allowed to remain until the carbonate of barium, formed by the CO_2 of the air with the solution, sediments, after which, by means of a 30 c.c. pipette, that quantity of the supernatant clear fluid is pipetted off into a clear glass flask, two drops of the indicator are added, and it is titrated by the standard oxalic acid. The quantity of acid needed to discharge the pink colour is again noted.

Having ascertained the alkalinity of the Baryta water both before and after exposure to the air of examination, it now remains, after noting the temperature of the air, to calculate the result.

Let us say that the cubic contents of air-jar = 5060 − 60 for space occupied by Baryta water.

Causticity or alkalinity of Baryta water—

Before exposure, required of oxalic acid = 39·5 c.c.
After exposure, „ „ = 33·5 c.c.

∴ 39·5 − 33·5 = 6 c.c. = Half amount of Baryta water changed into carbonate by amount of CO_2 in air in jar.

But 1 c.c. of standard oxalic acid equals 0·25 vol. of CO_2. ∴ 0·25 × 6 = 1·5 vols. of CO_2 in *half* the amount of Bartya water taken.

∴ 1·5 × 2 = 3 vols. of CO_2 in total air-contents of jar.

The calculation, therefore, works out thus :—

$5060 - 60 : 10{,}000 :: 3 : x.$ $x = 6$ vols. per 10,000 of air.
= ·6 vols. per 1000 „
= ·06 vols. per cent. „

For very accurate work, temperature and pressure during the experiment

must be taken for calculation at standard temperature and pressure – 0° C., and 760 m.m.

Vo = vol. at 0° C.,
Vt = vol. at t° C.,
a = ·00366 = co-efficient of expansion for 1° C.,

$$\therefore\ Vo = \frac{Vt}{1 + at}.$$

Thus, suppose in the foregoing test the temperature was 15·5° C. ; to ascertain the volume of air in jar at 0° C. :

$$Vo = \frac{Vt}{1+at} = Vo = \frac{5000}{1 + \cdot 00366 \times 15\cdot 5} = Vo = \frac{5000}{1\cdot 05673} = Vo = 4731\cdot 76 \text{ c.c.}$$

If it be desired to correct for both temperature and pressure, the following formula may be used :—

$$Vo_{760} = \frac{Vt \times b}{(1+at) \times 760}.$$

Where b = barometric pressure found during experiment; the other terms remaining as above.

Pettenkofer's Tube Method.—The reagents and standard solutions used are the same as in previous method. The apparatus consists of two tubes A and B, the one placed above the other, both connected with each other and with an aspirator C, of known cubic capacity, by means of tight rubber tubing. 100 c.c. of Baryta water are put into each tube, the connections duly made, and thereupon air is drawn slowly in a series of fine bubbles through the tubes, by opening the tap of the aspirator. The quantity of air to be tested is regulated by the size of the aspirator. At the end of the experiment, the contents of tubes A and B are emptied into separate, clean, glass-stoppered flasks, to allow precipitates of Barium carbonate to subside. Meanwhile, 50 c.c. of stock solution of Baryta water is being titrated against standard oxalic acid, and the number of c.c. required are noted. When the exposed Baryta water has cleared, 50 c.c. of the supernatant clear solution of each bottle are pipetted off, titrated as described, and each result multiplied by 2 ; the sum of both equals, after calculation, the total CO_2 in the total volume of air passed through.

Of the two methods of Pettenkofer this is certainly the more accurate, although the needed apparatus is not so portable in the latter.

Professor Walker of Dundee has suggested a modification of Pettenkofer's Flask Method. This consists in using a Winchester quart, the rubber stopper of the mouth of which is perforated to enable two glass tubes provided with stop-cocks to be passed. By means of one of these tubes 50 c.c. of $\frac{N}{50}$ Baryta solution are introduced into the bottle, and the air contents shaken up for about fifteen minutes. After this the Winchester bottle is inverted, and the contained Baryta water passed into a Soxhlet apparatus with asbestos or glass-wool filter connected with a filtering flask charged with 10 c.c. of $\frac{N}{10}$ hydrochloric acid, which, in turn, is connected with a filter-pump. By means of the filter-pump and stop-cocks, the air-bottle is washed out three times with neutralised distilled water, this operation being completed with entire exclusion of atmospheric air. The excess of hydrochloric acid is now titrated back with $\frac{N}{50}$ Baryta water, and the quantity required is the measure of the amount of CO_2 present in the air of the jar, since the carbonate of barium formed is arrested in the Soxhlet filtering tube, and consequently the alkaline barium solution is less in valency as is the excess of hydrochloric acid. Walker claims for this process an accuracy which in no case varies on one side or other of the truth more than 0·1 volume in 10,000 of air.

Hesse's Method.—The apparatus consists of A, the reserve laboratory portion, and B, the portable portion.

A consists of (1) *Stock saturated solution of Baryta water*, made by dissolving in 4 to 5 litres of water, 1 kilo. of hydrated oxide of Barium, $Ba(OH)_2$, and 50

grammes of Barium chloride, $BaCl_2$. As the solution is used to make the working solution, water is added so long as the barium compounds are in excess to saturate the water ; (2) *Working solution* of the same ; the bottle which contains it being provided with absorption flask containing pumice stone saturated while hot with heated Caustic potash, to arrest CO_2 of the entering air as the solution is siphoned off as needed ; (3) Standard Solution of *Oxalic Acid*, containing 5·6325 grammes pure acid per litre of distilled water, of which 1 c.c. = 1 c.c. vol. of CO_2 ; (4) *Alcoholic solution of phenolphthalein*, 1 to 250.

B consists of (1) five thick-walled Erlenmeyer flasks of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{12}$, $\frac{1}{16}$-litre-capacity respectively, exact cubic capacity of each of which to lower level of fitted rubber stopper has been carefully ascertained and marked on flask. Each flask is fitted with a 2-holed rubber stopper, the holes being fitted with pieces of glass rod well rounded at lower end and button-shaped at top ; (2) thick-walled 10 c.c. pipette ; (3) Burette, with glass stop-cock, of 25 c.c. capacity and graduated in tenths, having a spit or tip from 7 to 10 centimetres in length ; (4) Flasks of 300 c.c. capacity, provided with absorption bottles and filled with solution of baryta water (No. 2 above), to which a few drops of *rosolic acid* have been added to faintly colour the contents ; (5) Bottles of 250 c.c. capacity, filled with Oxalic Acid solution, made by mixing 25 c.c. of strong acid solution (No 3 as above) with distilled water up to 250 c.c. : 1 c.c. of solution = ·0056325 gramme of oxalic acid = ·01 c.c. vol. of CO_2; (6) thermometer (Cent.) ; (7) Aneroid or Mercurial barometer.

By this method each determination of CO_2 is made in duplicate, but with different volumes of air. Thus, $\frac{1}{2}$ and $\frac{1}{4}$, or $\frac{1}{4}$ and $\frac{1}{8}$, or $\frac{1}{4}$ and $\frac{1}{12}$-litre flasks are used together, depending upon likely impurity of air.

Modus operandi.—Take samples of air by first filling flasks with water at place of examination and temperature of place, and then emptying them in the room, rinsing with distilled water, and draining dry, care being taken neither to warm flasks with the hands, nor to breathe into them. Then take the stopper of flask to be used, pass through one opening of it a 10 c.c. pipette ; insert point of pipette into delivery tube of dilute baryta water ; fill to 10 c.c. mark ; place stopper in position in mouth of air-flask ; drain pipette-contents into flask ; then withdraw pipette and quickly close opening with glass rod. Repeat the process with the second smaller air-flask. Allow air-flasks to stand for about 15 minutes or more, with occasional agitation, to absorb CO_2. In the interval, titrate the alkalinity of 10 c.c. baryta water in $\frac{1}{16}$-litre flask with oxalic acid solution (No. 5 as above) until colour is discharged ; note number of c.c. of acid required. Then proceed to titrate the baryta water in air-flasks, *without removing barium carbonate formed*, in the following manner: Remove glass rod from one hole of stopper, quickly insert in its place the long-spitted burette filled to zero mark with oxalic acid solution, titrate carefully, with rotatory motion of flask, until colour is discharged, and note number of c.c. required. Should contents of burette cease to run during the process, gently ease the glass rod of second opening. Proceed with second air-flask in like manner ; then calculate results to normal temperature and pressure, and take the mean of results as the amount in volumes of CO_2 present in 10,000 volumes of air of samples. This process, when carefully conducted, gives most accurate results.

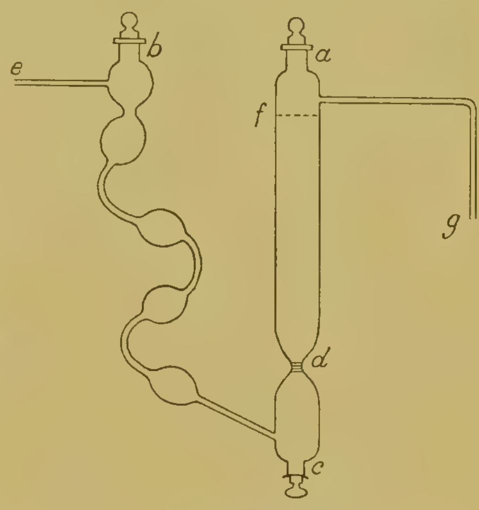


FIG. 143.—Wolff's Apparatus for Testing for Carbon Monoxide.

Detection of small amounts of Carbon Monoxide in Air.—The best qualitative method is that of Vogel, which is based upon the formation of a compound of the gas with hæmoglobin known as carboxyhæmoglobin. Wolff's apparatus is excellent for the application of the test. It is prepared in the following way: Close constric-

tion at d with a plug of glass wool, fill tube d to f with glass, powdered as fine as ordinary gunpowder, after sifting, digesting with HCl, washing with water, and drying it; moisten it *in situ* with distilled water; apply water-pump connection at e, to drain through surplus water, which is run off by stopper c; thereafter, drop over glass powder 2 c.c. of dilute blood (prepared as below) 1 to 40; gently blow through g to distribute blood solution evenly through glass powder; attach aspirating vessel of known capacity at e, and aspirate through about 10 litres of air at the rate of about 1 litre per 20 to 25 minutes. When room air is being examined, the air ought first to be passed through a glass cylinder containing pumice stone moistened with water, which may be attached at g. When the above quantity of air has been passed, from 3 to 5 c.c. of distilled water should be added to tube-contents at a, the aspirator disconnected, and the water-pump connected, so that the blood solution and added water shall be drawn through into lower part of tube, which may be removed at c for spectroscopic examination. After the operation is over, the glass powder should be washed clean with water and drained, ready for other experiments. The blood solution to be used is obtained by mixing fibrin-free blood with an *equal volume of cold saturated solution of borax*, since by this addition decomposition is prevented, the spectroscopic properties are not interfered with, nor is the action with ammonium sulphide. One c.c. of the mixture added to 19 c.c. of distilled water is the strength to be used, and 2 c.c. is the quantity for each experiment. The above test will detect ·05 per cent. of carbon monoxide in air. The blood is thereafter examined spectroscopically by the direct-vision spectroscope for the characteristic bands of carboxyhæmoglobin (*vide* p. 242).

Methods for Detection of Organic Matter in Air.—(*a*) Wanklyn's method of estimating organic matter in terms of ammonia. Connect with an aspirator of known capacity a wash-bottle containing 50 to 100 c.c. of ammonia-free water, which is placed in ice or a strong solution of ammonium nitrate. Aspirate through the water not less than 5 to 10 litres of air. At end of experiment place contents of wash-bottle, after addition of 100 c.c. of ammonia-free water, into a retort connected with Liebig's condenser, and distil for *free* and *albuminoid* ammonia as in the process for water analysis (*q.v.*). After Nesslerising, calculate results into volumes of air used, and state in terms of ammonia per 100,000 or million volumes of air.

(*b*) Carnelly's process. Reagents required: (1) $\frac{N}{100}$ solution of $KMnO_4$ = ·316 grammes of salt per litre of freshly distilled water; (2) $\frac{N}{1000}$ solution of the same, made by mixing 100 c.c. of $\frac{N}{100}$ solution with 50 c.c. of dilute sulphuric acid (1 to 10), and making up to one litre with distilled water; (3) Dilute sulphuric acid (1 to 10).

Apparatus required: (*a*) large air-jars or Pettenkofer's tubes; (*b*) burettes and pipettes; (*c*) bellows.

Modus operandi.—Fill air-jar of known capacity with air to be examined; add 50 c.c. of $\frac{N}{1000}$ $KMnO_4$ solution; and wash well, by agitation, air of jar with solution for 5 to 10 minutes. Having prepared two *chemically clean* Nessler or Hehner glasses, *A* and *B*, into *A* put 25 c.c. of $KMnO_4$ solution from air-jar, and add to 100 c.c. mark with distilled water, and into *B* put 25 c.c. of $KMnO_4$ solution from $\frac{N}{1000}$ stock bottle, and add to 100 c.c. with distilled water. Compare the colours in the glasses. There will be decolorisation in *A* in proportion to amount of oxygen used up by organic matter of air in air-jar, or the amount of air passed through the Pettenkofer tubes, if such have been used instead of an air-jar. From a burette charged with $\frac{N}{1000}$ K MnO_4, drop into glass *A*, with stirring, such a quantity as will make colours of *A* and *B* exactly alike. The amount added will be half the measure of oxygen used up. Multiply the number of c.c. required by two, and the answer by ·0056 to bring oxygen to volumes; calculate

the result into one million volumes of air examined. Thus: suppose 25 c.c. of solution from air-jar required 3 c.c. of $\frac{N}{1000}$ solution to make colours in *A* and *B* alike; then $3 \times 2 = 6$ c.c. for total solution used, and $6 \times {\cdot}0056 = {\cdot}0336$ volumes of oxygen used up by air-contents of jar. But the capacity of air-jar is 3500 c.c. less 50 c.c. air-space taken up by solution added, viz.:—3450 c.c.

then 3450 c.c. : 1,000,000 : : ·0336 : x

$\therefore x = 9{\cdot}74$ volumes of oxygen per million volumes of air are required to oxidise organic matter present.

Corrections must be made for temperature and pressure. The above test when used for testing the air of a room in which artificial lights, other than electric, have been used, is open to the objection that decolorisation of the permanganate solution is affected by oxidisable products of combustion, and, therefore, the result cannot be taken to be truly representative of organic matter given off from the bodies of the occupants. Moreover, it is sometimes difficult to exactly match the colours. At the same time, the test is probably the best available for estimating organic matter in air.

CHAPTER V.

HEATING AND LIGHTING.

The sources of heat in occupied apartments may be summed up under the following, viz.:—

(*a*) Open Fires, which consume coal or wood ;
(*b*) Closed Stoves, which consume coal, wood, or oil ;
(*c*) Gas Fires ;
(*d*) Hot-water Installations, at ordinary pressure ;
(*e*) Hot-water Installations, at high pressure ;
(*f*) Steam-coils.

(A) *Open Fires.*—The open fire still holds, in this country at least, the premier position as the source of heat in houses. It sends out radiant heat which is stimulating and exhilarating ; this warms the objects which it strikes—the bodies of the occupants, objects of furniture, walls of room—and the room to a greater or lesser extent is thereby warmed. It least of all directly warms the air. It is without question the most healthful form of heating, for not only does it provide heat, but it also gratifies the senses as no other form can.

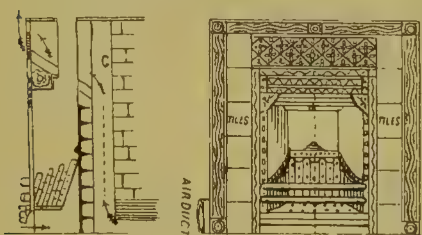


FIG. 144.—Griffin's Grate.

The objections, from the economical point of view, which have been urged against it, and with much truth, are, (1) that its heating effect is most unequal, since the intensity of radiant heat is in direct proportion to the temperature of its source, and inversely as the square of the distance from the source; hence the greatest amount of heat is in the immediate vicinity of the fireplace ; (2) that it is most wasteful of fuel with relation to the amount of heat given off into the room-atmosphere ; indeed, in an ordinary fireplace it may be reckoned that from five-eighths to three-fourths of the total heat generated is of no value to the apartment. From the economic standpoint these are cogent objections. Probably the first objection will always more or less obtain, no matter the kind of fireplace used, or the mode of consumption of fuel which is adopted. (Fig. 144.) But improvements may be instituted to remedy the objection with respect to unnecessary waste of fuel. This waste is due to two factors chiefly, viz., (*a*) faulty construction of fireplace, grate, and throat of chimney, and (*b*) the mode of consumption of fuel. In ordinary use, probably about one-third of the coal passes off in smoke which produces no heat, but only assists in contaminating the general atmosphere outside. This may be called active or *quick* combustion, as contradistinguished from *slow* com-

bustion which is accomplished by regulating the amount of air to be supplied to and which is required by the fire for combustion. In ordinary or quick combustion, the air-supply passes through and from beneath the fire-seat; in slow combustion, it is only permitted to pass through the fire-seat. In consequence of the reduced air-supply, combustion is less rapid, the fuel lasts longer, and the air-movement in the flue is slower; so that for a smaller quantity of fuel, a larger amount of heat is conserved for heating the apartment. From a long-continued series of practical experiments with different forms of grates, we have found that not only is the slow-combustion grate the most economical of fuel, but that more heat per unit of fuel is given off into the room. The simpler the form of grate the better. We devised the following grate for an apartment of about 6000 cubic feet capacity. It consisted of a plain metal frame placed "flush" with the wall of the room. The floor was composed of one large thick firebrick, and the sides and back were formed in the same way. The outer lining

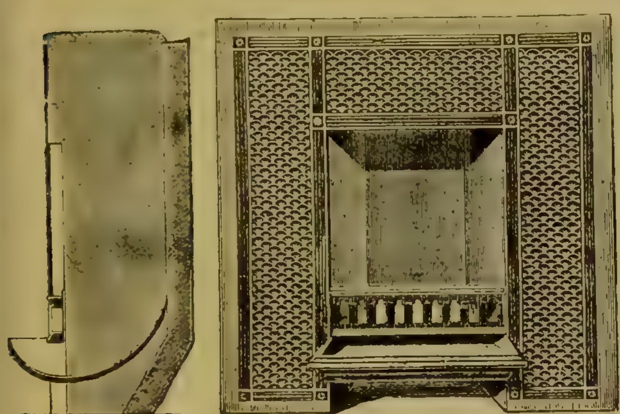


FIG. 145.—Brown and Greene's Grate, to aid in smoke-consumption. By means of a specially constructed shovel fresh coal is put into the fire, on the curved ledge shown in the section, below the incandescent coal.

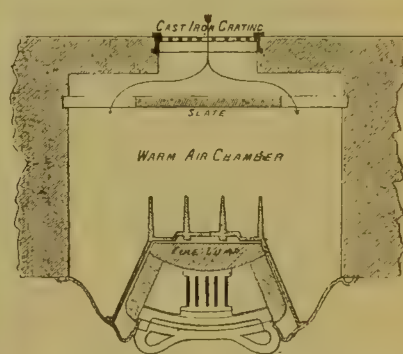


FIG. 146.—Section of Galton's Grate. Through the grating behind the fireplace passes fresh air, which being warmed by the heat of the fire in the grate, passes into the apartment.

of the fireplace, behind the side and back bricks, was built up of fire-clay bricks set in cement. The throat of the flue was contracted and rounded in cement. To start the fire, a blower, which consisted of a sheet of iron, was made, which fitted into a sliding socket in the upper part of the grate frame, and which could be pulled down when required, and replaced when the fire was started. Such a fire required to be replenished but twice daily; and even after it was out, much heat was given off from the fire-bricks. Another advantage of the slow-combustion grate is that objectionable draughts are less likely to be produced between the windows and door and fireplace. While these grates would not be an absolute cure for smoky atmospheres, there is no doubt that smoke-production would be greatly reduced. Other forms of grates have been devised with the avowed object of smoke-prevention. Fig. 145 shows one form in which the fresh coal is placed in the fire by a specially constructed shovel on the curved ledge shown in the section below the incandescent coal. Next to petroleum, coal gives off per unit more heat than any other form of fuel.

(B) *Closed Stoves.*—To some extent these are used in this country, but they are more commonly employed in countries which experience more rigorous winters. They economise fuel. They, however, warm the air of the room more than the objects in it, and they do not act so efficiently as exits for foul air as the open grate. They are made of cast iron, either solely, or with an external covering of porcelain slabs or tiles. Such stoves are by no means impervious to the gases of combustion, not only from the loosening of the joints and seams consequent upon alternate expansion and contraction, but when red hot they are pervious to carbon monoxide. The source of this gas is still an open question; it is doubtful whether it is due to imperfect combustion of the coal, to the oxidation of the organic matter of the air coming in contact with the heated metal, or to the combustion of the carbon contained in the iron of the stove itself: all of these causes have been suggested. Probably the chief objection to their use lies in the fact that they "dry" the air of the room; in other words, they produce upon the occupants the sensation of dried air. The effect is by no means imaginary, and is caused in the following way. As we have already seen, the quantity of watery vapour in the air at any given time is dependent upon the temperature of the air; in other words, for each temperature there is a maximum amount which the air can sustain, called the *saturation point*. Most commonly, however, air only holds some percentage proportion of this; and most comfort is experienced when that proportion is from 70 to 80 per cent. If we assume that when a stove is lighted, the temperature of the air of the room is 40° F., and that it then holds 75 per cent. of watery vapour for that temperature, when the room temperature has risen to 65° F., the percentage of humidity *for that temperature* will become less than 75 per cent., since the total amount of watery vapour capable of being sustained increases with rise of temperature; consequently, the air feels dry to the occupants. What happens, then, is this. The air robs the bodies of the occupants of moisture to satisfy its needs, and hence the skin begins to feel dry, the hair crisp, and an indefinable sense of discomfort supervenes. This is commonly overcome by placing shallow vessels containing water in the vicinity of the stove.

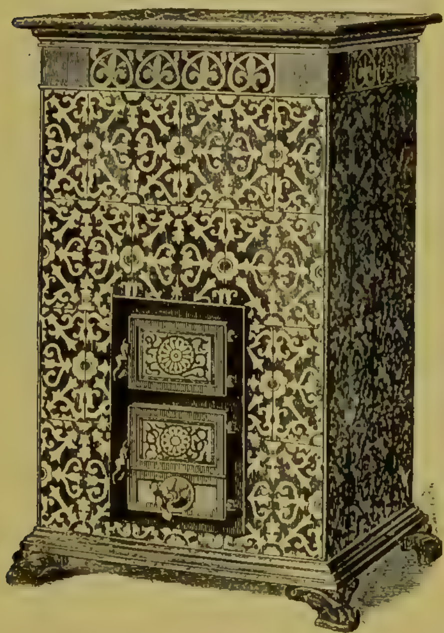


FIG. 147.—Doulton's Tiled Stove. *Vide* Fig. 129 for section plan of stove.

(C) *Gas Fires.*—It may be conceded at once that gas fires are handy, cleanly, and comparatively cheap as sources of heat. For cooking purposes, especially in summer, they can be used as needed, and so they save the needless expenditure of coal fuel. But as a source

of heat in rooms, except in bedrooms where they are used only for a short time before retiral to bed, we are decidedly against their use. We have tried practically many forms, but have discarded them all. All the objections which have been offered against coal stoves have greater force against these, not only from the point of view of efficiency, but chiefly from that of health. Perhaps the least objectionable form is that in which a series of Bunsen jets is fitted into an ordinary grate filled with chunks of asbestos or fire-clay, since some of the radiant heat of the coal-fire is provided, and there is an ample flue for the escape of the products of combustion. The same, however, cannot be said of those gas-heaters which are provided with flue-pipes of one half to one inch diameter only. Such flues are worse than useless; indeed, they are delusive and dangerous, especially where coal-gas contains an admixture of water-gas, or of carburetted gas which is rich in carbon monoxide, because of the inadequate provision for carrying away the products of combustion or unconsumed gas due to a choked burner or one which has struck back. Flueless gas stoves are positively harmful, unless sufficient provision be made to neutralise by absorption the resultant gases of combustion. Those which profess to do this are still on their trial; and until some special provision has been made to absorb carbon monoxide, which is exceedingly poisonous, and at the same time odourless, they cannot be deemed safe or healthy. Acetylene is liable to be given off from gas fires where the Bunsen burners become choked, or strike back. This gas is very irritating to throat and lungs, and is apt to exercise prejudice to the health of those exposed to it. This, however, is not an objection to the use of gas as a fuel, but to its improper use. At the same time, the generation of acetylene is very common from want of attention, while its rectification is easy. Upon the whole, it appears to us that the drying of the air is greater with gas fires or stoves than even with coal stoves. The special field of usefulness of the gas fire is that of cooking.

Oil stoves are objectionable also from the health point of view. There is no practical difference between burning several wicks under cover of coloured glass and burning several single lamps; they equally consume air, and for equal quantities of heat consume more oxygen than coal-gas. Besides, they are usually unprovided with flues of any kind, and are calculated, therefore, to charge the atmosphere with excess of CO_2. Another objection to their use is the disagreeable odour of acrolein which is produced by the combustion of poor oils, or of oil in an imperfectly cleaned stove.

In short, all stoves heat the air of the room by conduction; the open fire, by radiation. The former do not act as efficient outlets of foul air—indeed flueless stoves, not at all; the latter acts more or less efficiently. Whatever faults the open fire possesses, it is much superior from the point of view of health than any kind of stove.

(D) *Hot-Water Installations: At Ordinary Pressure.*—Heating by pipes containing hot water about a temperature of 180–200° F. is in common use in large public buildings, such as halls, churches, hospitals, schools, barracks, and the like. It is coming into use, however, in large private dwellings. The heated pipes, which are

composed of cast iron, warm the air of the apartment by conduction, or convection. Provided special arrangements are made for the ventilation of the apartment, little or no objection can be offered to their use. The only precaution which requires to be taken is that the contents of the cold-water supply-cistern should be prevented from freezing. Such an occurrence is by no means unknown. Moreover, in view of possible cessation of the public water-supply for a period of time, it is advisable to have a reservoir-cistern to fall back upon when needed. In the system, the boiler is the lowest point, and the circulation depends upon the fact that heated water becomes lighter and rises, cools in passing along in the pipes, and falls by gravity back to the boiler. The allowance for heating surface per thousand cubic feet of air to be heated is twelve feet of 4-inch piping. Hood, in his treatise on Warming and Ventilation, shows that one foot length of a four-inch pipe containing water at a temperature 125° F., above that of the surrounding air, will raise 222 cubic feet of air one degree of temperature per minute; that is, about 190 cubic feet for every superficial foot of surface of pipe. In order to calculate the necessary extent of piping required to heat any given confined space, he recommends that the total cubic space in feet be multiplied by the number of degrees of temperature desired, and that the product be divided by 190 into the time, reduced to minutes, within which the desired temperature is to be attained; the answer will be the number of superficial feet of pipe required. Careful allowance must, at the same time, be made for windows and open ceilings. When a temperature of 60° F. above that of the external air is wanted, the rule is to add one foot of piping for every two and a half feet of glass superficies.

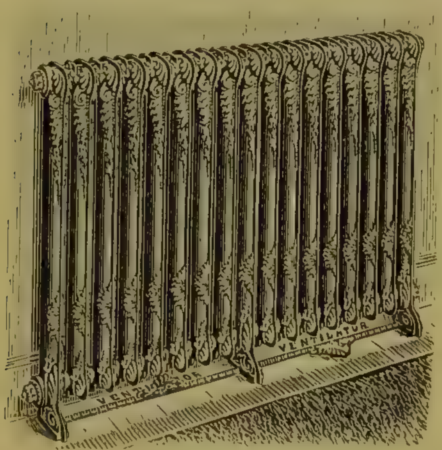


FIG. 148.—Hot-Water Radiator.

(E) *At High Pressure.*—This form of installation, in which the water is heated under a pressure of three or four atmospheres, is fitted with pipes of smaller diameter than in the previous system, which are made of wrought iron. They are thick in the wall and their internal diameter is half an inch. The pipes form a continuous system, shut off from the air, except at the highest point where an expansion branch-pipe is placed to prevent explosions. There is no boiler in the system, the water being heated by a length of the pipe, usually from about one-tenth to one-sixth of the total, placed in the furnace. The temperature of the water is usually about 300° F. By reason of this, the extent of piping required is less than in the other system. It is commonly estimated that 8 or 9 feet of piping is equivalent in heating-power to 12 feet of the other.

(F) *Steam Coils.*—Steam is also used in pipes for warming purposes, and either at high or low pressure. In workshops and factories

where steam-power exists, the waste steam is usually employed for this purpose. The size of pipe to be used necessarily depends upon the area to be warmed. Connected with the steam-pipes, at suitable points radiators are placed. In these, the calibre of the pipes is purposely made larger than that of the supply-pipe, so as to favour condensation and thus favour the liberation of latent heat; but it is necessary that facilities be provided for the rapid return to the boiler of the condensed vapour. Probably the only large experiment of heating the homes of a community by steam is that which was carried out in Lockport, America. The steam can be turned on and off at will in each house in the circuit, and it can be employed for heating or cooking, or as a motive power. In all of these systems by hot water or steam, valvular arrangements exist at suitable points whereby the circuit can be closed, or the circulation regulated. Where such systems are installed it is necessary to have separate arrangements for ventilation.

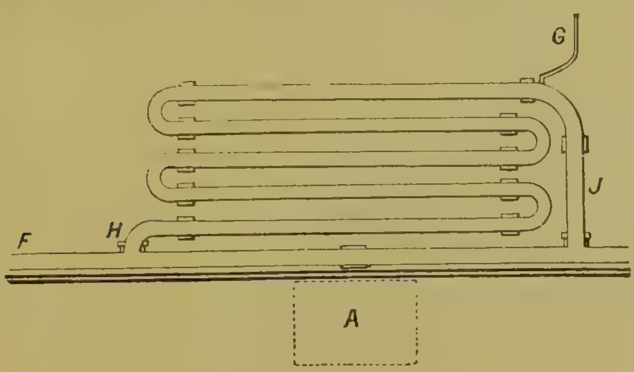


FIG. 149.—High-Pressure Hot-Water Coil for heating air of apartment and also in-coming fresh air at A. F, main hot-water pipe; H, J, branch coil-pipe; G, expansion pipe.

In America especially, and in other countries, the use of warmed air supplied from hot-air furnaces is very prevalent. The furnace is usually situated in the basement, and from it hot-air flues are distributed through the various apartments. While in this country most comfort in winter is attained by a temperature of about 65° F., it would appear that in America, that is effected by one of 70–75° F., by reason of the less humid condition of the atmosphere. Water vessels however, are usually necessary in the apartments, because of the dryness of the air which is produced.

FIG. 150.—System of Heating Houses by Steam.

LIGHTING AND ILLUMINANTS.

Lighting.—Of the artificial illuminants now in use, the principal in the order of prevalence are the following, viz. :—

(*a*) Coal-gas.
(*b*) Oils—burned in lamps.
(*c*) Electric light.

In the two first-named, the illumination is produced by the combustion of inflammable gases or vapours ; in the last, from the passage of an electric current which, by reason of resistance offered to its further progress, raises a carbon filament to a state of active incandescence, or carbon pencils to a white incandescence. In the last, the amount of combustion is but small. The consumption of coal-gas and of the hydro-carbons of oils mainly produces carbonic acid and water ; if, however, the gas be imperfectly purified, traces of sulphur gases and ammonia are also found. During combustion they use up the oxygen of the air. Electric lighting is not accompanied by any consumpt of oxygen, and therefore, unlike the others, does not contribute to the vitiation of the atmosphere, inasmuch as no carbonic acid is produced.

(A) *Coal-Gas.*—This is composed of a mixture of gases, which may be divided into illuminants, diluents, and impurities. Of the first, the chief are ethylene, propylene, acetylene, and benzene ; of the second, hydrogen, marsh gas, carbon monoxide ; and of the last, nitrogen, carbon dioxide, sulphuretted hydrogen. In 100 parts, the first form about 6·5 parts, the second about 90 parts, and the last about 3·5 parts. The exact composition of coal-gas depends upon the character and quality of the coal from which it is made ; that from cannel coal being richer in illuminants than that from bituminous coal. Of the illuminants, the principal is ethylene, or, as it is more commonly termed, carburetted hydrogen or olefiant gas. The products of the combustion of gas per 100 parts are composed as follows: nitrogen, about 67 per cent. ; water, 16 per cent. ; carbonic acid, 7 per cent. ; carbon monoxide, 6 per cent. ; in addition to traces of sulphurous acid and ammonia. The chief results of the use of coal-gas upon the air of room are increase of carbonic acid and watery vapour, heightening of temperature, together with the production of carbon monoxide, and, when improperly consumed, the passage of unconsumed constituent gases and unconsumed carbon into the room atmosphere. It exercises, moreover, a destructive influence upon articles in the room, as books, pictures, wall-paper, etc., and is not cleanly. Each cubic foot of gas consumed may be reckoned as polluting the atmosphere to the same degree as one adult, since it gives off half its volume (0·52) of CO_2 and 1·34 cubic feet of watery vapour. Many ingenious contrivances in the form of improved burners to ensure the regulation and better consumption of gas have been devised, and some of these have been associated with ventilating flues by which the products of combustion are carried out of the apartment. In the regenerative gas-burner of Siemens, there exists an arrangement whereby, in a chamber heated by the products of combustion, air

and gas are warmed prior to their admixture and ignition. After the products have become heated in the mixing-chamber they are discharged into the open air. Probably the best form of gas consumption is that attained by the Welsbach incandescent light. It consists essentially of a Bunsen burner, surmounted by a mantle of fine network composed of asbestos which has been treated with a solution of a zirconium salt. The mantle, by reason of the intensely hot non luminous flame of the Bunsen, becomes incandescent and emits a brilliant white light, and for equal quantities of gas consumed, gives more than one and a half times the light of the Siemens burner. It is now being introduced into street lighting. Since coal-gas has become so much used for heating purposes, various towns in this country and in America have added certain proportions of water-gas or of carburetted water-gas. This has given rise to many fatal accidents, because of the large proportion of CO which it then contains.

Acetylene gas, C_2H_2, generated by the action of water upon calcium carbide, is now becoming adopted for small installations of lighting. Its use is not unattended by danger from risk of explosions due to admixture with air in proportions of from 4 to 25 per cent., but doubtless this risk will be overcome. It gives a strong, clear, white light. The products of combustion are solely CO_2 and watery vapour.

(B) *Oil Lamps.*—Good oils burned in suitable lamps give an exceedingly good, mellow light, although they all raise the temperature of the room air on combustion and give off much CO_2 and watery vapour. Kerosene oil, in addition, however, contributes traces of sulphurous acids. Oil is much used in the country and in small towns as a matter of necessity, and by many persons in populous places, as a matter of choice.

(C) *Electric Light.*—If the prime cost of installation and cost of generation of the electric light could be reduced it would become the prevalent light of private houses as well as of the public streets, for undoubtedly it presents enormous advantages over the other illuminants from the point of view of health. In the first place, as there is no consumption of the air of the apartment, so are there no vitiated products returned to it; and in the second, during its operation, but trifling heat compared with other illuminants is generated. According to certain authorities, small quantities of nitric acid are produced from the arc light. Of the two systems of lighting, viz.: the incandescent and the arc, the former is more adapted for the lighting of apartments, the latter for public halls and streets. The former possesses a mellow, yellowish light which is more agreeable to the vision than the arc light, which is white and dazzling, and which, moreover, is rich in the violet and ultra-violet rays of the solar spectrum. There can be little doubt that by the more general use of the incandescent system of electric lighting the health of persons, who, by employment or otherwise, are exposed for hours together to artificial illuminants, would be better conserved than at present, and more general comfort would be ensured. Since the introduction of this form of lighting into a church frequented in the evenings by crowded

audiences, the number of fainting attacks, which when coal-gas was in use were very common, has now been reduced to a minimum; moreover, there has been a substantial reduction in the temperature, and in the sense of oppression of the atmosphere from the former time. In the use of electric light, special provisions must be made for ventilation, since in the absence of the generation of heat by the lighting, the motive power of the other illuminants is absent; however, coal-gas may be used as a sunlight-burner at the mouth of an outlet ventilator situated on the roof-ridge, in the case of halls, churches, and the like, since, up till now, the installation of coal-gas is maintained alongside that of electricity. However, the advantages produced by electric lighting far outweigh any possible disadvantage, and are vastly superior to those of any other illuminant.

The following Table presents some of the chief comparative characteristics of the principal illuminants.

Table XIII.

Table Illustrative of Illuminants.

Illuminant.	Amount consumed.	Candle-power.	Cubic Feet of Used-up Oxygen.	Cubic Feet of CO_2 produced.	Moisture produced.	Heat Calories produced.
Tallow Candles . .	2200 grains	16	10·7	7·3	8·2	1400
Sperm Candles .	1740 ,,	16	9·6	6·5	6·5	1137
Paraffin Oil Lamp .	992 ,,	16	6·2	4·5	3·5	1030
Kerosene Oil Lamp .	909 ,,	16	5·9	4·1	3·3	1030
Coal-gas Jet, No. 5, batwing burner .	5·5 cub. ft.	16	6·5	2·8	7·3	1194
Coal-gas, Argand burner . . .	4·8 ,, ,,	16	5·8	2·6	6·4	1240
Coal-gas, Siemens burner . . .	3·2 ,, ,,	32	3·6	1·7	4·2	760
Coal-gas (Welsbach incandescent light)	3·5 ,, ,,	50	4·1	1·8	4·7	763
Electric Incandescent	0·3 lb. coal	16	0·0	0·0	0·0	37

This Table, which we have taken from Notter and Firth's treatise on Hygiene, p. 141, shows the following comparative facts, viz.: (1) that for equal candle-power light the Welsbach light uses by far the least gas, uses up less oxygen, and gives off least CO_2, of all the gas lights; (2) that oil-lamps use up more oxygen, and give off more CO_2, than gas-lights, for equal candle-power; (3) that electric light neither uses up oxygen, nor gives off CO_2; (4) that for equal illumination, coal-gas as ordinarily consumed gives off most heat after tallow candles, oil lamps next, then the Siemens and Welsbach lights, and electric light least of all.

CHAPTER VI.

WATER AND WATER-SUPPLY.

WATER, like air and food, is one of the prime necessities of life, animal and vegetable. It enters into the composition of everything in Nature. The human body itself is made up of 75 per cent. of water, hence the daily individual need is not inconsiderable. Water is a potent factor also in personal, domestic, and public hygiene; hence the need for an abundant supply. The public health largely depends upon a good supply and the free use of water; and a water famine is disastrous to the health of a city, as it is also to the public economics, since so many trade processes, not to speak of steam-raising, require daily much water. Where, too, the carriage of sewage depends on the water-supply, reduced supplies mean imperfect flushing, and, therefore, impurity of sewage channels, and consequent risks to health. Chemically pure water does not exist in Nature, although it is found approximately pure.

Sources of Supply.—The original source of all the water on the earth's surface is the ocean. From the surface of the sea the heat of the sun drives off by evaporation huge quantities of watery vapour into the higher reaches of the atmosphere, which is there condensed as clouds, and is returned to the earth as water, either in the solid or liquid form. Having fallen upon the surface of the earth, it depends upon the configuration of the land upon which it falls, and upon its geological structure, whether the rain mainly sinks into the earth, or collects upon its surface. But in any case, there is formed an underground or subsoil collection of water, and also an overground or surface collection; the level of both at any given time depending upon the antecedent rainfall. By digging a shaft into the earth, this underground supply may be tapped, but the depth of the well so formed will depend upon the level of the underground water. That part of the rainfall which does not percolate into the soil forms lakes and rivers. Springs arise from the underground water, which, in the course of downward percolation, encounters an impervious rock stratum, which, dipping out on the surface of the land, causes the water to travel along its upper level, and thus to appear at the earth's surface. Water-supplies are obtained from the following sources, viz.: (1) rivers; (2) lakes; (3) springs; (4) wells, and (5) rainfall (directly). These demand separate consideration.

Rivers.—In its virgin condition, a river is but a moving column of rain-water, containing in solution what the water may have dissolved in its passage through the air, on its way to the river in the various rivulets or contributaries, and in the river-bed itself. In such a con-

dition, a river is a good source of supply. Hence rivers are tapped as water-supplies; less, however, now than formerly, owing to increasing pollution of streams. But those which pass through moorland, high-lying, uninhabited tracts of country are still available, and afford excellent supplies. London still depends to a large extent for its supply upon the Thames and its tributaries. Aberdeen is in a like position with respect to the Dee; and many other towns in addition. Most rivers, however, with the exception of those parts of their courses above-named, are so polluted by sewage and trade refuse that they must be looked upon as suspicious sources of supply, and before the best of them even can be used efficient filtration must precede distribution for consumption. There are those who contend that a river will purify itself of organic pollution in the course of its flow. The Rivers Pollution Commissioners in their sixth Report state quite decisively "that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." We shall return to the question of river pollution later.

Lakes.—These are natural upland collections of water, and constitute the source of our purest supplies. Located in high-lying, sparsely-inhabited areas, they are little liable to contamination; formed on rock strata difficult of solution, they contain but little mineral matter; constituted only of water from the rainfall, their waters are soft, and therefore excellent for washing purposes; but, surrounded by large areas of bogland and moorland, they usually contain vegetable organic matter from the decomposing peat, etc., which, in some cases at least, exercises a plumbo-solvent action on the service-pipes, and also imparts some degree of colour to the water. *Reservoirs* are but artificial lakes, formed in similar districts for similar reasons. They are formed by building an artificial embankment at a suitable point, which impounds the water of one or more small streams. These are constructed of such a size as to contain a sufficient quantity of water to supply the inhabitants of the district to be supplied for a period of 150 to 180 or more days. In all such cases, since the flow of water to down-stream consumers is seriously interfered with, Parliament insists that compensation water, to the extent usually of one-third of the total quantity impounded, must be allowed to pass by into the river, to ensure constancy of which supply compensation reservoirs must usually be formed. The institution of such reservoirs as a source of water-supply involves very important engineering questions, not only with respect to compensation water, but also with respect to the size of the reservoir to be constructed, since it includes consideration of such important points as the following, viz.: (*a*) suitability of site; (*b*) sufficiency of supply, depending upon the mean annual rainfall of the district for a series of years, and the maximum and minimum rainfall, and upon dry weather and mean flow of streams impounded; (*c*) amount in gallons to be supplied per head of population per day; (*d*) number of days' supply to be stored; and several others. From the public health point of view, the important questions are: (1) sufficiency of supply, (2) number of gallons per head per day to be allowed, and (3) number of days' supply to be stored. To estimate

the number of days' supply which must be stored, where the source of supply is the rainfall, Hawksley's formula is applied.

$$x = \frac{1000}{\sqrt{y}}.$$

Where x = the number of days required;
y = the mean rainfall of the three lowest consecutive years.

The total quantity of water yielded by a catchment area of known size, the rainfall also being known, may be computed by Pole's formula, viz. :—

$$x = 62\,A\left(\frac{4}{5}R - E\right).$$

Where x = the total yield of water in gallons;
A = the area of gathering ground, or catchment area in acres;
R = the mean rainfall of the three lowest consecutive years;
E = the loss of water by evaporation, waste, and percolation.

The amount of loss by percolation will obviously depend upon the character of the soil, and may therefore vary between ten and twenty inches per annum; but in most localities of the upland type, it is nearer the lower than the higher figure. For every inch of rain 101 tons, or 22,617 gallons, of water fall upon one square acre of land.

Many important cities derive their water-supplies either from natural or artificial upland lakes; of these Glasgow, Edinburgh, Manchester, Liverpool, Dublin and others may be cited. The source is often at great distance from the point of distribution; in the case of Glasgow it is about 30 miles, of Manchester 90 miles, and of Liverpool 68 miles.

From the reservoirs, the water passes by outlet pipes into the aqueducts, either direct to the place of distribution, or to secondary reservoirs within a few miles of that point, in which latter case it is passed from the secondary reservoirs by distributing mains through the streets of the area of distribution, from which houses are supplied by service-pipes.

Springs.—These usually supply but limited amounts of water, sufficient in quantity, however, in many cases to be a source of storage and supply for limited collections of houses.

Wells.—These constitute the chief source of water-supply of isolated houses of rural districts, including farms, and even of some small towns. The purity of the water of farm wells is of prime importance with relation to the milk-supply and the spread of enteric fever. Wells may be divided into three kinds, viz.: (*a*) Shallow or Surface; (*b*) Deep; (*c*) Artesian; and these designations do not depend so much upon their actual depth as upon their relation to the earth strata through which they are driven. A shallow or surface well is one which, sunk into pervious soil, taps the underground water which has percolated from the surface of the ground within the immediate vicinity of the well shaft. A deep well is one which, sunk through the pervious surface-layer of soil and an underlying impervious stratum of rock, taps the underground water which has percolated from the land-surface

at some distance from the well-shaft. An Artesian well (so called from the province of Artois in France, where they were first discovered) is one in which the shaft is sunk through (1) a pervious layer, (2) an impervious layer, and which taps a collection of water lying on the top of (3), another impervious layer of rock, the two latter of which "outcrop" on the land surface at a higher point than the top of the shaft, and, it may be, at a distance of many miles from the shaft or bore. The conditions in which an Artesian well is possible, or likely, are these: (*a*) that a water-carrying layer, depressed in the centre and reaching the ground surface at the extremities of the dip, should be situated between two impervious strata; (*b*) that this porous water-bearing layer is not interrupted by any impermeable wedge; (*c*) that there is no source of escape of the contained water in the impermeable layers; (*d*) that the level of the ground at which the boring is made is not higher than the extremities of the water-bearing layer. It will thus be seen that the geological conditions necessary are those of cup-shaped formation.

The same geological conditions obtain in the case of spouting oil-wells, if an oil-bearing stratum be substituted for the water-bearing

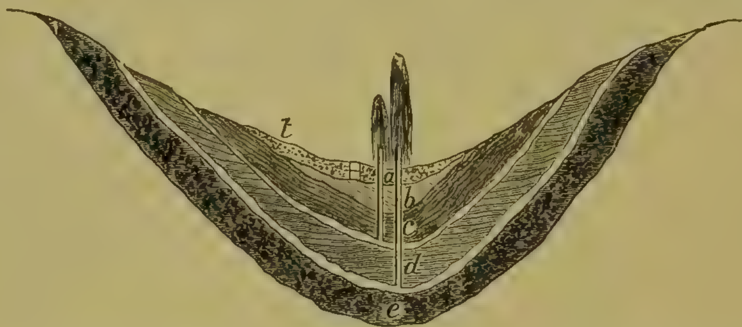


FIG. 151.—Figure represents a vertical section of Geological Strata of a water-bearing Basin. a = layer of loose sand and gravel; b = bed of clay; c = stratum of slate; d = limestone stratum; e = a stratum of granite. The upright shafts are spouting bore-tubes or Artesian wells.

stratum. The water which is tapped in Artesian wells, falls upon the area of land covered by the water-bearing, porous layer, and sinking into this basin-like formation, lies there under considerable pressure. When the bore-tube, in the process of sinking, reaches the water-bearing layer, the pressure on the masses of water lying between the impervious layers forces the water up the tube, and occasionally into the air above the level of the head of the bore-tube. Such wells are commonly of great depth; that of Grenelle, in Paris, is 1800 feet; of Passy, 1900 feet; and of Rochefort, 2765 feet. The discovery of such sources of supply in the comparatively waterless districts of Australia, where immense herds of cattle and sheep are grazed, has proved of inestimable value, since, under former conditions during periods of prolonged drought, millions of these animals perished for lack of water. Of 454 bores which have been made, 317 overflow, and the total daily outflow of water amounts to over 193 millions of gallons daily. Some of these bores are as deep as 4000 feet; more common depths, however, are 1600, 1700, and 1800 feet

respectively. Owing to the depth of Artesian wells, their water is high in temperature; that of Grenelle is 82° F., that of Rochefort, 106° F., and in some of the Australian wells it is as high as 180° F. They provide large quantities of water; that of Grenelle, for example, gives 500,000 gallons daily, and this well obtains its supply from an area 100 miles from Paris; in the Australian bores, the daily output varies in different wells, in some 700,000, in others 1,500,000 and 3,000,000 gallons daily.

Many towns in England derive some of or even their chief supplies from Artesian wells. Among these may be named Canterbury, Cambridge, Bury St. Edmunds, Deal, Coventry, Leamington, Southport, Bedford, Scarborough, Hatfield; and at Uxbridge, Berkhampstead, Chesham, and other places, they have been sunk for supplies for water-cress growing, while in places where a suitable hard water for brewing purposes is not obtainable, bores have been sunk by brewers to obtain such supplies.

From Rainfall directly.—In rural districts, where other sources of supply are either not available, or are too costly to utilise, the rainfall may be stored, under certain conditions, for potable purposes. In hard-water districts it is stored for washing purposes. Besides, there are certain places as Aden, in which the sole source of supply is the rainfall, which is collected in reservoirs in the rocky reaches above the town. But the rainfall cannot be used in populous and manufacturing centres because of the impurity of the air. The gathering-ground of the rainfall for an individual house is the roof. But since that surface is apt to be polluted in various ways, by bird-droppings and dust for example, all the rain which falls cannot be used. It is advisable that the first part of a rainfall should be rejected. To meet these conditions, an ingenious arrangement called Roberts' Separator has been devised. It is constructed in sizes which bear a certain ratio to the superficies of the roof-area, and is so arranged that when a sufficient amount of rain has fallen to cleanse the roof, the water first collected is tilted into a waste channel, and the after-fall is directed into the collecting channel and reservoir. It is always better that the rain-water, even when so collected, should be subjected to filtration, which is easily accomplished by underground filters.

The quantity of water which may be collected annually from the roof of a house may be calculated by knowing the following data, viz.: (*a*) the superficies of the horizontal area of the roof; (*b*) the average annual rainfall; (*c*) the average amount of evaporation. From the total calculated amount must be deducted from one-quarter to one-third for waste, evaporation, etc.

Example.—What amount of water might be collected annually from the roof of a house whose horizontal area measures 250 square feet, the annual rainfall being 27 inches?

$$\begin{aligned} &250 \text{ feet} \times 2\tfrac{1}{4} \text{ feet} - \tfrac{1}{4} \text{ for waste} \\ &= 562{\cdot}5 \text{ cubic feet} - 140{\cdot}5 \text{ cubic feet} \\ &= 422 \text{ cubic feet} \times 6{\cdot}23 \\ &= 2629 \text{ gallons.} \end{aligned}$$

Qualities of Water from Different Sources.—The Rivers Pollution

Commissioners (Sixth Report) classified waters as to palatability and wholesomeness in the following way:—

Wholesome	Spring water	very palatable.
	Deep well water	
	Upland surface water	moderately palatable.
Suspicious	Stored rain water	
	Water from cultivated land	palatable.
Dangerous	River water	
	Shallow well water	

It is important to note that suspicious or even dangerous waters may be perfectly palatable, and may even present a bright, sparkling appearance, partly due to gases produced from the decomposition of contained organic matter and partly to the contaminated soil.

Water collected upon the surface of the oldest rocks, the metamorphic, granitic or quartzose, trap-rock, grey slate, or greensand is good, wholesome, palatable, and invaluable for potable purposes. Such waters contain but small quantities of dissolved mineral matter, and are therefore soft; having fallen through a pure atmosphere, they are well aerated; but they are usually tinged in colour with peaty products and vegetable organic matter. From the chemical point of view they contain little total solids, are free from suspended matter, contain little chlorine, little or no free ammonia, more than usual albuminoid ammonia, but no nitrates or nitrites, the oxygen consumed is small, and they possess but a few degrees of hardness.

Water from chalky, limestone, magnesian, or ferruginous strata, though it is likely to be wholesome, palatable. and potable, possesses the disadvantage economically that it is hard, because of the carbonates of lime, magnesia, or iron which are dissolved in it. In water from the former two classes of strata, sulphates of lime and magnesia are likely to be present in addition to the carbonates, and may even form the chief cause of the hardness. Waters which contain the carbonate of iron are called chalybeate waters. With the exception of the mineral salts which they contain, such waters are usually pure, contain but little chlorine, free ammonia and albuminoid ammonia, and consume but little oxygen. It ought to be understood, however, that certain hard waters derived from rocks on the sea-board may contain what might at first sight appear to be excess of chlorine, and certain others from Artesian wells not only contain excess of chlorine and mineral solids, but also nitrates, due to the bore having reached strata of an old sea-bed, the waters otherwise being organically pure. Waters from the Wealden clay, London clay, and greensand share the same tendency to hardness, and the like characters as to purity. Waters which come from the coal-measures are apt to contain sulphur, either as sulphates or as H_2S, as well as iron. Water from gravel-beds is likely to be pure or impure depending upon proximity to filth-deposits.

The following Table gives the views of the Rivers Pollution Commissioners on the relation of source of supply to hardness; the first-named being the softest, and the last-named the hardest:—

TABLE XIV.

Table showing Relation of Hardness of Water to Source of Supply.

a Rain water (softest).
b Upland surface water.
c Water from cultivated land.
d River water.
e Spring water.
f Deep well water.
g Shallow well water.

The only objection which may be offered to this Table is that in Scotland at least, shallow wells, except on the sea-board and in limited inland areas, usually contain soft water.

Source of Supply in Relation to possible Pollution.—The Table of the Commissioners already given indicates most accurately the relation of likely pollution to source of supply. About the time the Commissioners completed their inquiries, the bulk of the population obtained their water from contaminated sources; since then, however, supplies have been improved. The only likely source of pollution of upland surface supplies is from cultivated land, but this is practically never found in the supplies from the higher uplands. Part of the existing water-supply of Glasgow, for example, is obtained from the hilly ground to the south of the city. It was the main source of supply before the institution of the Loch Katrine scheme. The gathering-ground of this supply contains not a little cultivated land; and it may be taken as a type of the catchment-area of middle upland supplies. All supplies from such sources contain organic matter in questionable quantities, and therefore ought to be, as they mostly are, filtered. The water of rivers, except near their source perhaps, is polluted more or less by animal organic matter, and, in many cases, cannot be safely used without constant and adequate filtration. Shallow well supplies should *a priori* be considered as contaminated when in the vicinity of inhabited houses, until proved to be otherwise.

Hardness and Softness.—These are terms which are employed to express the difficulty or ease with which water unites with soap to form a lather; in other words, the soap-destroying power of a water. Economically, this is of importance in a manufacturing community and for domestic uses. Every degree of hardness in a water destroys $1\frac{1}{2}$ lbs. of soap per 1000 gallons; hence a water of 10° and 20° of hardness will require 15 lbs. and 30 lbs. of soap respectively per 1000 gallons. Owing to the installation of the Loch Katrine supply into Glasgow, the annual monetary saving in soap alone by the use of this soft water has not been less than £36,000, not to speak of the lessened expenditure of coal for steam-raising purposes by the absence of "fur" in boilers. The hardness of the London supplies compels an annual expenditure in soap alone of about £250,000. Waters differ much as to hardness or softness; that of Glasgow, for example, having only about 1° to $1\frac{1}{2}$°, those of London from 12° to 21°, and that of Sunderland 30°. The Table already given indicates, generally, the relation of source to hardness or softness. Hardness is due to the presence of salts of lime and magnesia, alumina and iron, of chlorides, carbonates, and sulphates of the two first, and of the carbonate of iron. The carbonates are formed from solution of lime-

stone, magnesian limestone, and ferruginous strata by the CO_2 dissolved by the rain as it percolates into the earth's crust. The *rationale* of soap-destruction is as follows: Hard soap is a compound of various fatty acids with soda; it is, therefore, chiefly composed of the stearate, oleate, and palmitate of soda. On being melted in a water containing lime and magnesian salts in solution, they decompose the soap and unite with the oleic, stearic, and palmitic acids to form these salts of lime, which, however, being insoluble in water, float like curdy flakes on its surface. So long as lime or magnesia is present ununited with these fatty acids, no lather will form; but when excess of soap is added, lathering takes place. Hardness is distinguished as existing in waters in one or other or both of the following forms, viz., *removable* or *temporary*, and *irremovable* or *permanent*. Removable or temporary hardness is so designated because it may be removed by boiling, and the other form as irremovable or permanent, because it cannot be so removed. As has been said, the carbonates of lime and magnesia exist in solution by excess of CO_2—indeed, they may be presumed to be in the form of bicarbonates—and when the water is boiled and the excess of CO_2 is thus driven off, the calcium and other carbonates are thrown out of solution, and become visible as a milky sediment, according to the following equation :—

$$CaOCO_2CO_2 = CO_2 + CaCO_3.$$

This calcium carbonate, along with any magnesium carbonate present, is, therefore, liable to become deposited on the interior surface of boiling vessels, as hot-water boilers, kettles, hot-water pipes, etc., as a "fur" or "scale." This deposit, in turn, compels the increased use of fuel to generate steam, or the institution of measures to prevent furring, it corrodes the boiler-plates, and gives rise to boiler-explosions from the consequent thinning of the plates. Any hardness which remains after boiling is called permanent hardness. The sum of both *temporary* and *permanent* hardness constitutes *total* hardness. It is not impossible, however, even to reduce the so-called permanent hardness by chemical means. By addition of carbonate of soda, double decomposition takes place with the formation of sodium sulphate and carbonate of lime, the latter being precipitated in the boiling. This process is used in the Desrumaux system of water-softening.

Effects of Impure Water on Health.—Impurities in water which are apt to affect health are divisible into two classes, viz., (*a*) those which have their source in filth or sewage contamination; (*b*) those of the nature of mineral or other constituents. The second class is, probably, of lesser vital importance than the first.

From the impurities falling under the first head, may arise cholera, enteric fever, diarrhœal diseases and dysentery. The sewage-polluted and unfiltered water of the Elbe, in 1892–93, caused a very widespread and fatal epidemic of cholera in Hamburg and Altona. Hamburg, with a population of 640,400, had 16,907 cases, or 264·8 per 10,000, with 8606 deaths, while the coterminous town of Altona, with 148,600 of population, using the same water-supply but filtered

through sand, had only 516 cases, or 34·6 per 10,000, with 316 deaths. The origin of outbreaks of enteric fever in polluted water-supplies has been proved in all civilised countries. The following Table[1] indicates some of the principal epidemics of this and other countries from water-supplies.

Table XV.

Table of Epidemics from Polluted Water.

Year.	Place.	Disease.	Population.	Cases.	Deaths.
1867	Guildford	Enteric Fever	...	250	...
1867	Terling, Essex . . .	,,	900	260	...
1872	Lausen (Switzerland) .	,,	780	130	
1874	Over-Darwen . . .	,,	22,000	2,035	104
1878	Caterham	,,	...	179	...
1882	Bangor, North Wales .	,,	10,000	540	...
1882	Wittemberg Barracks .	,,	386	66	...
1885	Plymouth, Pennsylvania .	,,	9,000	1,000	...
1887	Mountain Ash, Wales .	,,	...	over 500	...
1889	New Herrington, Durham	,,	3,600	278	..
1890–91	Tees Valley . . .	,,	...	1,463	...
1892–93	Hamburg . . .	Cholera	640,400	16,957	8,606
1893	Paisley	Enteric Fever	...	over 800	...
1896	Dunbar	,,	...	...	..
1897	Maidstone, Kent . .	,,	...	1,938	...
1897–98	Philadelphia . . .	,,	...	1,927	...
1898	Paisley	,,	...	279	34

Note.—(...) signifies that the number is not noted.

The pollution may arise in the gathering-ground or reservoir, as in the Maidstone, Plymouth, Pa., Dunbar, and Paisley epidemics; from wells, as at Guildford in 1867, New Herrington, Durham, in 1889, and at Morningside, Edinburgh, in 1894. In the New Herrington case, it was shown that the pollution of the deep well had its origin in the sewage of a farm three-quarters of a mile away, and in that of Edinburgh, from sewage in a quarry 800 feet distant from the well. In the Wittemberg Barracks epidemic of 1882, the cause was leakage of enteric sewage through the cracked cemented walls of the well, and in that of Caterham in 1867, to a workman employed at the water-works who was suffering from enteric fever of a slight degree, defæcating in a shaft leading to the water conduit. The epidemic of Lausen, Switzerland, in 1872, was due to contamination of a spring by the sewage of a farm-house, some distance away, finding its way by a subterranean channel. River-supplies are also constantly liable to pollution, and give rise to enteric fever epidemics. Those of Bangor, N. Wales, in 1882, of the Tees Valley in 1890–91, of Philadelphia in 1897–98, and others, are cases in point. Not only may pollution occur at the source, but it may arise, also, in the distributory channels. The epidemics of Over-Darwen in 1874, of Mountain Ash, Glamorgan, in 1887, and of Paisley in 1898, may be cited as examples.

[1] Paper by the Author, "The Supervisory Control of Water-Supplies" (*Sanitary Journal*, 1900).

Short of enteric fever, outbreaks of an anomalous character have occurred from time to time in different places. In Hull, some years ago, about 20,000 of the inhabitants were attacked with diarrhœal disorders by reason of ditch water finding its way into the supply reservoir.

Dysentery is endemic in Egypt, in South Africa, and in other parts of the world from polluted water. Certain parasitic diseases, too, which affect man, are also traceable to water which contains the ova of certain parasites, or their mature forms. The Mount Gothard outbreak, due to the *Ankylostoma duodenale*, is an instance. In like manner, it is believed, may *Tænia solium*, *Tænia echinococcus*, and other tape-worms, *Ascaris lumbricoides*, *Oxyuris vermicularis*, *Filaria perstans*, *Bilharzia hæmatobia*, *Filaria dracunculus*, and other parasites find a nidus in the human body. There is also good reason to believe that such microbic diseases as anthrax and glanders, have been propagated among animals from the water of public drinking-troughs, by specific contamination from infective cattle or horses.

(B) *From Mineral or other Constituents.*—The mineral constituents of water. when abundant, are apt to engender not only discomfort but disease. Persons who for nine or ten months of the year use soft water for potable purposes and food-preparation, are very liable at first to gastro-intestinal disturbance when they remove for a summer holiday to a district where the water is hard. This is particularly true of those with a rheumatic or gouty diathesis. Constipation alternating with diarrhœa, or continuous diarrhœa, with gastric catarrh and dyspepsia, are common effects, until acclimatisation is established. Certain definite diseases have been for ages attributed to the constant use of hard water. Goître, or "Derbyshire neck," and cretinism are the chief. By some observers these affections are declared to be due to the sulphates of lime and magnesia in the water, and by others, to certain metallic sulphides, notably that of iron. In Switzerland, the Himalayas, Cochin China, and the Pyrenees, as well as at home, cretinism, which consists of a rickety condition of the osseous system, associated with imperfect development of the brain indicated by imbecility, is by no means uncommon. Norris, about half a century ago, described the endemic cretins of the village of Chiselborough in Somerset. This village lay in a valley hemmed in on all sides but one by hills over 400 feet high. Its population numbered 540; of these two to three hundred were goîtrous, of low intelligence and defective speech, 20 were cretins, and 5 goîtrous deaf-mutes. All these have now practically disappeared under improved sanitary conditions. As to the origin of these affections, much striking evidence has been adduced. McClelland, quoted by Hirsch,[1] says of the province of Kuman in the Himalayas, that in 91 villages situated on granite and gneiss, hornblende slate and mica-slate, green sandstone, grassitine, and silicious sandstone, with a total population of 5383, there were 29 goîtrous persons and no cretins, but that in 35 villages on Alpine limestone, with a population of 1163, there were 390 cases of goître and 34 of cretinism. A French Commission

[1] "Handbook of Geographical and Historical Pathology," vol. ii. p. 175 (Syd. Soc. Ed.).

[?] and at Chelmsford in 1903, about 1400 inhabitants were attacked with a like disorder owing to manurial matters which had been washed into a water-reservoir by the exceptionally heavy rainfall. (Thresh, B.M.J. Sept 26 1903 Vol II p. 710)

See also Report of New York State Board of Health for 1898, where is recorded an outbreak of dysenteric diarrhoea traced to a water-supply which had been contaminated by soil, the intimate cause of the mischief being attributed to B. pyocyaneus.

appointed to make investigation on this subject, obtained some remarkable evidence, as, for example, the following: In 1848, in a town called Bozel (Tarentaise), of a population of 1472 persons, 900 had goître and 109 were cretins, while the village of St. Bon, situated about 1100 yards higher than Bozel, was free from both diseases. Each had its own separate water-supply, that of Bozel was a hard water containing magnesium and lime sulphate, and that of St. Bon was a soft water. A pipe was laid from St. Bon to Bozel conveying this soft supply. Sixteen years later—1864—in Bozel, the number of goîtrous persons had fallen to 39, and of cretins to 58. Against this, however, must be placed the contrary experience of such places as Sunderland, where the water is of 30° hardness, principally due to sulphates of lime and magnesia. While, therefore, the causal relationship of hard water and goître appears to be so close, it has not yet been clearly determined that lime and magnesium salts alone are the causative factors. In 1898, Grasset of Montpellier communicated to the French Academy of Sciences the results of investigations, extending over ten years, on persons suffering from goître in the Puy-di-Dôme department of France. In the blood of eight persons suffering from recently acquired goître—from ten to fifteen days—Grasset found special hæmatozoa. He describes them as spherical bodies larger than a red blood-corpuscle, non-nucleated, containing red pigment, and possessing a free flagellum. Although they resembled the hæmatozoa described by Danilewski, Grasset avers that none of the patients were malarious. From the existence of this hæmatozoon, Grasset believes goître to be infectious. These observations, it must be added, have not yet been sufficiently confirmed to enable it to be definitely affirmed that the disease is due to a hæmatozoon.

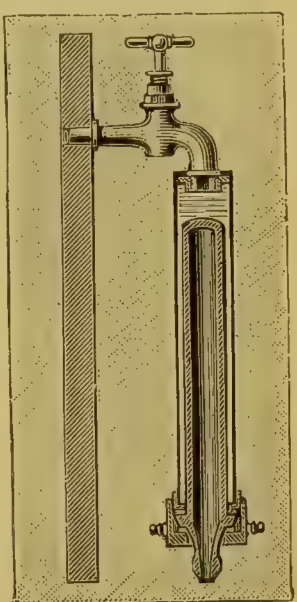


FIG. 152.—Pasteur-Chamberland Filter.

Purification of water on the small scale: (1) *Boiling*.—Those impurities in water due to sewage contamination which are most dangerous to health and life may be got rid of, on the small scale, by boiling and by filtration. Since, however, boiled water loses its piquancy of flavour, due to the atmospheric gases which it contains having been driven off, it is necessary to re-aërate it to make it palatable. This may be done in a variety of ways, as by pouring it from one vessel to another, preferably through a rose-opening, or a sieve. *Household filters* are the means adopted to purify water from suspended matter. Much has been written in condemnation of these filters, but their failure seems to consist in their inability to arrest micro-organisms, and also that the filtering media are not cleansed sufficiently often. But provided that the media are re-purified at regular short intervals, their action is not only safe, but fairly efficient as regards suspended matters. The filtering media in most

common use are: (1) carbon, animal or vegetable; in powder or in block, and alone, or combined with manganese, silica, or iron; (2) sand, solid or in grains; (3) iron, in some form, as spongy iron, polarite, magnetic carbide of iron, and iron combined with charcoal and clay, called carferal; (4) asbestos, as in Maignen's *Filtre rapide*. To purify the carbon and asbestos, it is only necessary to heat them to a red-heat, and the others, by washing several times with boiling water. The only filters which do not permit the passage of microbes are the Pasteur-Chamberland and Berkefeldt, the former of which consists of a bougie or hollow candle of unglazed, or "*biscuit*" porcelain, and the latter of tubes of compressed diatomaceous earth. These bougies are enclosed in a metal case, which may be screwed on a water-tap, or be connected with a small tank. Even these require frequent and careful cleansing, because of their ability to arrest the finest suspended matter; and this is best accomplished by subjecting the bougies to a red-heat, after preliminary washing and brushing.

FIG. 153.—Bougies for Pasteur-Chamberland Filter.

(2) *Distillation* is the method commonly employed on board steamships. Distilled like boiled water has a flat taste, and, therefore, must be re-aërated to restore its flavour. It is free from organisms and dissolved solids.

(3) *By Addition of Chemical Substances.*—These have been tried mainly with armies in the field to overcome the delay consequent upon boiling or sterilising the water-supplies. In the Soudan, our army used a form of bromine process, the French have tried potassium permanganate, alum, and chalk, the Belgians an apparatus for generating hydrogen peroxide, the Austrians, calcium hypochlorite; but all have been found ineffective. Parkes and Rideal[1] have experimented with a great variety of chemical agents to produce sterilisation of water, and of these, probably the most efficient and most active were tartaric acid and acid sodium bisulphate. The latter salt, it is stated, destroys the *B. typhosus* after five minutes' contact in a solution containing 15½ grains to the pint of infected water, *i.e.* one part of the salt to about 565 parts of water. It has been found better, however, to permit of fifteen minutes' contact. It is believed, moreover, that if men on the march were supplied with the salt in the form of 5-grain tabloids that thirst would be lessened and the immediate hunger for water stayed until efficient sterilisation of supplies by certain methods could be achieved.

Purification of water on the large scale is effected by sedimentation and filtration; and these are necessary in all waters derived from catchment areas containing arable land, and from rivers. Sedimentation is allowed to take place during the period of stay in a large reservoir, and the action of gravity causes suspended matter, coarse and fine, to fall, and in doing so to entangle in it micro-organisms. In the term sedimentation must be included the effects of sunlight, for the diminution in number of micro-organisms per c.c. which follows sedimentation must be partly attributed to the operation of both

[1] *B. M. J.*, vol. i. 1901, p. 242.

causes. In the case of the London companies, the average number of microbes is reduced from 16,000 per cubic centimetre to numbers varying from 1000 to 7800. It has been clearly demonstrated from the experiments of Delépine and others, (1) that sedimentation is an important factor in the bacterial purification of water, and (2) that the best results appear to be obtained when the flow of water in a reservoir is sufficient to prevent stagnation, and, at the same time, to enable gravity to operate. In large water-works, sedimentation is achieved by abundant area of storage-reservoirs. But *filtration* must be deemed as the most important factor in purification. While the filter-beds may be constructed of different total depths of filtering-media, and the constitution of the filter-bed differ in different cases, it may be said that a filter-bed is composed, from above downwards, of (1) a layer of sharp sand, (2) gravel or broken shells, and (3) small boulders or large gravel. It would appear, however, from experiments of many observers, that the efficiency of filtration does not depend so much upon the total depth or composition of the filter-bed, as upon the rate of filtration and the formation of a gelatinous scum on the surface of the filter-bed. In London, where filtration is carried on on the largest scale, the depth of the water on the filter-bed is never greater than two feet, and from this the average rate of filtration per square foot is 42 gallons per twenty-four hours. One hundred acres of filter-beds are employed by eight London companies, and the efficiency of filtration may be gathered from the fact that the number of organisms per c.c. is reduced from 16,000 to numbers varying between 35 and 100; and according to Frankland, the number of micro-organisms in unfiltered Thames water at Hampton is reduced by over 97 per cent., on the average, by sedimentation and filtration. The experiments of the Massachusetts Board of Health clearly prove that, under the following conditions, filtration would remove fully 99 per cent. of organisms, viz.: (*a*) a filter-bed of sand of 60 inches in depth, the average size of sand grain being ·09 millimetre; (*b*) a rate of filtration of two million gallons per acre per day. Koch, indeed, has laid down the principle that no water should be permitted to enter a service reservoir which contains more than 100 organisms per c.c. The highest point of efficiency of a filter-bed is not attained, as might *a priori* be expected, immediately after it has been set in operation, or has been renewed, but until some days—five to ten or more—after it has been working. This points to the fact that water-filtration is not merely a mechanical straining operation, but is something more. When the surface of a filter-bed is examined after about twelve days' work, a thin gelatinous layer, or film, will be found to have formed. This seems to be a biological filter, in which the micro-organisms are arrested. Upon examination, this film or scum is found to consist of organic matter and bacteria. The life of a filter-bed for efficient action will depend upon the character of the water to be filtered, but in the cases under consideration, it lasts for from three to six weeks or longer. At the end of this time, the filter-bed is allowed to run dry, and the top inches of sand are removed, and washed rid of organic débris in a washing-machine, while they are replaced by clean sand.

Softening.—By reason of the economic and other disadvantages of hard waters, it has been found desirable to soften water on the large scale. For this purpose, several processes are in vogue; such as those of Clark, Porter-Clark, Howatson, Atkin, Desrumaux, the Stanhope, the Lawrence, and others. The original of these was Clark's, and was applied at the storage-grounds. The *rationale* of the process was to remove the hardness due to the carbonates of lime and magnesia, by adding freshly slaked lime in defined proportions, depending upon the hardness. The added lime, taking up the excess CO_2 which kept these salts in solution, forms fresh carbonate of lime and magnesia, throws the original salts out of solution, and the whole are precipitated together. The reaction which takes place for the lime is this: $CaOCO_2CO_2 + Ca(HO)_2 = 2CaCO_3 + H_2O$. The factors to be known for its practical application are these: (*a*) the cubic contents, or quantity in gallons in the reservoir, the water of which is to be softened; (*b*) the number of degrees of temporary hardness of the water.

Clark's rule was that for every 100,000 gallons of water, 6 lbs. of freshly-burned lime for each degree of hardness were to be added; therefore, for waters of 10°, 15°, or 20° of hardness, the necessary quantities of lime would be 60, 90, or 120 lbs. respectively. The lime to be added being mixed in a tank with 500 to 1000 gallons of water, the bulk to be purified is made to pass slowly through it. The water thereupon assumes a milky hue, due to the carbonates in suspension which have been thrown out of solution, is then allowed to settle to permit of precipitation, the supernatant water is drawn off, and is reaërated by passing it over an artificial weir composed of a rough surface. In the other processes, lime alone, or lime mixed with sodium carbonate, or with alumina in addition is used. But the great difference between Clark's original process and some of the other processes named is the mode by which the precipitated lime is got rid of. In the Porter-Clark process, the suspended lime and water are passed through filter-presses at high pressure. The same general arrangements are present in Atkin's system, but the deposit on the filter-sheets is rubbed off continuously as it is deposited by revolving brushes. In the others, more or less complicated machinery is employed. It may be said of them all that they very efficiently accomplish their object: and the effect is to reduce the hardness by several degrees, varying from 12 to 15.

Quantity to be supplied per Head per Day.—The amount of water supplied per head per day in any community is necessarily determined by the total available amount at disposal. But there is a certain minimum quantity which is necessary. The average adult needs for nutrition, as a beverage and as a constituent of cooked food, from 70 to 100 ounces ($3\frac{1}{2}$ to 5 pints) daily. The soldier in barracks is allowed 15 gallons *per diem* for all purposes. The needs of a town are determined by the fact whether or not it is a manufacturing town, and what is the nature of the trade-processes. But in any case, the supply per individual may be apportioned as follows: (*A*) Dietetic: (1) cooking; (2) drink. (*B*) Sanitary: (1) personal ablution; (2) cleansing of clothing and home; (3) as a vehicle for sewage. If all of

these needs are summed up, probably from 12 to 15 gallons per day may be considered as a fair minimum. For all purposes, however, in a manufacturing town, where much water is necessarily employed, in addition to the foregoing allowance for such requirements as animal nutrition and cleansing and for municipal purposes, as cleansing of streets and courts, fire extinction, fountains, public baths and wash-houses, urinals, etc., a larger daily allowance is necessary; and the amount to be aimed at should not be less than 30 to 35 gallons per head daily; for although a certain allowance per head may be calculated from the total amount of water which leaves the reservoirs, it does not necessarily prove that such quantities are available to the consumers, because of waste from leaking mains and service-pipes, defective house water-fittings, and from wilful waste. Indeed, the amount of average waste has been reckoned to be from $\frac{1}{4}$ to $\frac{1}{3}$, or even a larger proportion of the total supply from these combined causes. Parkes' estimate of the supply needed per head per day, on the average of all towns, is as follows:—

		Gallons.
Domestic supply (without baths or closet) . .	=	12
General baths	=	4
Water-closets	=	6
Unavoidable waste	=	3
Total house-supply	=	25
Town, and trade-purposes, and for animals in non-manufacturing towns	=	5
For exceptional manufacturing towns . . .	=	5
Total	=	35

The daily amount per head available in different towns varies considerably. In London, the average amount is 28 gallons; in Liverpool, 30; in Paris, 31; in Edinburgh, 35; in Glasgow, 50; in Rome, 100; and in New York, 300; while in many towns it is less than 20 gallons.

Distribution of Water-Supply.—When populous places are to be supplied from natural or artificial upland collections of water, the relative altitudes of source of supply and area of distribution become of considerable importance, since if by gravity the water will flow from the source to the highest point of distribution, mechanical agencies can be dispensed with and money will be saved. Loch Katrine is 367 feet above sea-level, and Mugdock Reservoir, to which the water is led from the Loch and which is about six miles from the city of Glasgow, 317 feet. This relative difference of altitude, however, cannot always be secured, especially if the area of distribution covers a hilly tract of ground. In Glasgow, for example, one district at least cannot be supplied by gravity for this reason, and therefore an auxiliary pumping-station has had to be provided to drive the water to a reservoir situated higher than the houses to be supplied in that district. The following figure illustrates a gravitation water-supply (Fig. 154).

From the source the supply may be either *constant* or *intermittent*. This must be determined by the relation of available amount

of water in the reservoirs to the quantity required in the area of distribution; if it be abundant and greater than is needed, the supply should be constant; if, on the other hand, there be little margin to spare, it will probably be intermittent. The intermittent system of supply offers certain objections: first, it involves the need for erection of storage cisterns in houses wherein sufficient water is stored against the period in the twenty-four hours when the main-supply is cut off. Such cisterns are often sources of water-pollution from dirt, dead animals as mice, rats, beetles, etc., from plaster, or from coal-gas, etc., if they are not covered. Second: owing to the main-pipes being alternately full and empty, there is risk of contamination from sewage, sewage-gas, or coal-gas, by reason of the in-suction at leaking points. These risks are substantial. It has been urged that this system, however, has certain advantages, viz.: (1) there is less waste; (2) the water-fittings in houses need not be so strong. While the former may be true, it is difficult to see the force of the latter, except with respect to the water-fittings from the house cistern, since the pressure within the main-pipes and the service-pipes does not depend upon the constancy or intermittency of the supply, but upon the relative alti-

FIG. 154.—To illustrate Water-Supply by Gravitation. *a* = source of supply—a lake or reservoir; *b*=line of piping under pond or lake; *c*, *d* = fountains, to illustrate height to which the water will rise; *e*=storage cistern or reservoir; *f*=point of distribution, and limit to which water will rise.

tudes of source and point of distribution; in other words, upon the head of water. The great advantages of the constant system are: (1) the prevention of contamination in the main-pipes, since the pressure acts from within outwards, and (2) the avoidance of need of house-cisterns, with the attendant risks of contamination. Upon one occasion, by reason of continued ill-health of the inmates of a house, we examined the water-supply, and in the house-cistern, which was situated in the dark apartment containing bath and water-closet, we found the decomposing bodies of two rats and one mouse, in addition to dirty plaster. On analysis of the water, the existence of excess of free and albuminoid ammonia, organic matter, and nitrates showed that not only was pollution present, but that it had continued for some time. There is one unavoidable drawback in the constant system, and that is, when the water is cut off owing to repairs in mains, scanty supplies from drought, or other reasons. In such contingencies as the former, notice is usually given by the water companies when possible, so that water may be stored for the time being. Upon the whole, therefore, the aim should be abundance of quantity, a constant supply, and free access, public and private, to sources of supply.

Plumbo-Solvent Action.—Waters differ as to their power of dissolving lead, according to their composition. Soft waters, generally, have a plumbo-solvent power, due to the gases, oxygen and carbonic acid, which they contain in solution. But this statement must be received with a reservation. If a typical, soft water, as that of Loch Katrine, be experimented with, it will be found that it readily and freely attacks a bright, untarnished surface of lead piping, but that it does *not* attack a dull, tarnished surface. Therefore, when it is declared that Loch Katrine dissolves lead, that statement must be held to be only true of untarnished lead pipes, and not of tarnished. It is, doubtless, for this reason that lead poisoning is not prevalent in Glasgow and neighbourhood. Waters containing excess of chlorides, nitrates, nitrites, and organic matter also dissolve the metal. Such organic matter is usually composed of peaty products. Certain waters of Lancashire, Yorkshire, and Derbyshire derived from moorland gathering-grounds exercise this action distinctly, and symptoms of lead-poisoning have appeared in the consumers. On investigation, it was believed to arise from the presence of ulmic, humic, crenic, and apocrenic acids in the peaty organic matter. Neech of Halifax, in a report to the Health Committee of that town in February, 1901, pointed out that its water-supply exercised a marked lead-dissolving action. He found that when the acidity of the water was 1·01, the amount of lead dissolved in one hour was 0·56 parts per 100,000, when the acidity fell to 0·7, the dissolved lead also fell to 0·18 parts per 100,000. He found that by adding lime to the filtering-beds at the reservoirs to the extent of 80 to 90 grains per gallon, the acidity of the water was reduced to 0·31, and the dissolved lead to 0·037 parts per 100,000, which amount he believes to be within the limits of safe use.

This acidity of water as a main cause of lead-dissolving action seems to be corroborated by various facts. For example, after the long drought of 1887, during which the reservoir-supply of Sheffield fell much below normal, and when, therefore, it was believed that the water contained these acids in abnormally high proportion, a severe outbreak of lead-poisoning took place, which subsided on the water being restored to its usual level by rainfall. Some, however, are inclined to doubt the above explanation as the cause, and are more inclined to attribute the action to the work of micro-organisms. However, the fact remains that such waters do dissolve lead.

It is certain that peaty waters in some localities exercise this action, and that others in other localities do not. The interesting question then arises, What constituents exist in these waters which determine the difference of action? This has not yet been definitely established, but there is some ground for believing that the presence or absence of silica is a factor of importance. One thing is quite clear, that if a water possessing this power of plumbo-solvent action be filtered through a bed containing a proportion of silica, as where crushed granite is used as a separate layer below sand, or if a small quantity of silica be added to the water, the plumbo-solvent action disappears. It does not appear to us that solution of lead by potable waters is referable solely to one cause, but that the main cause probably is acidity of the water in the

service pipes. The presence of a minute quantity of lead, even to the amounts of $\frac{1}{10}$ to $\frac{1}{20}$ grain per gallon, is a serious matter, seeing that lead is a cumulative poison, and if this were discovered in a preliminary investigation into suitable waters for a new supply, it would rightly cause its rejection. But if this property is only discovered after the works are in operation, instant steps, by filtration especially and by other means, must be taken to rid it of this power. Probably the use of broken quartz, crushed granite, or other silicious material as a component part of the filter-bed, and in addition, the use of block-tin or glass-lined house-pipes, or even wrought-iron pipes, would produce the desired effect; at the same time, the whole question demands further investigation.

Hard waters also attack lead by reason of the excess CO_2 which they contain, but the salts of lead which are formed are insoluble, and

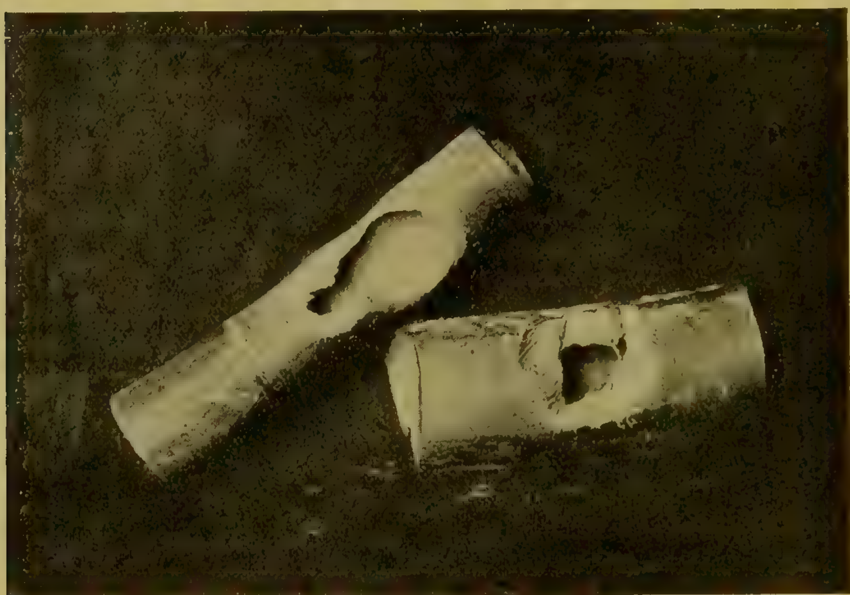


FIG. 155.—Water-pipes gnawed by Rats. The pipe on the left is 1 inch in diameter, and ⅛th of an inch in thickness. The other is 2 inches in diameter and $\frac{3}{16}$ths of an inch in thickness. (In possession of Author.)

therefore innoxious. Another enemy of water-pipes is rats. These rodents will attack pipes in their quest for water, and for the same reason are often found drowned in cisterns. The accompanying figure illustrates pipes in our possession which have been gnawed through by rats. (Fig. 155.)

Iron pipes, like lead pipes, are liable to oxidation, both externally and internally. The rust which forms in the interior offers a series of nuclei or foci for the deposition of organic matter and mineral matter in suspension, until sooner or later, diminution in rate of flow is produced by the lessened calibre. The interior of water-mains and service pipes of iron ought to be coated either with Angus Smith's composition (resin, oil, pitch, etc.), or by Barff's process, which causes a layer of magnetic oxide to be formed on the

interior of the pipe. The former, however, for months after, imparts a distinct tarry taste to the water.

Supervisory Control of Water-Supplies.—At the outset, it must be said that the total water-supplies of cities and towns in the kingdom are in the hands either of local authorities or of private companies; that by far the bulk of them are in the hands of the former; and that of the latter, there are, so far as we know, but *four* in all Scotland, whereas in England the number is much greater, there being eight in London alone. Supervisory control is necessary whether the water-company be the municipality or a private company, but it has been suggested, for different reasons, that in the case of private companies there should be greater freedom of access to sanitary authorities and water-consumers upon the lands of the water-company for the purposes of inspection and taking samples, if desired, than at present obtain. Supervisory control, therefore, divides itself into two kinds, viz.: (1) that which the vendors of the water ought to take for the purity of the water sold to consumers; and (2) that which the consumers ought to have for their protection where there is reason to believe the vendors are neglectful.

I. The nature of the supervisory control on the part of the vendors ought to include the following, viz.:—

(*a*) A knowledge of the original character and natural history of the water-supply;

(*b*) Inspection of the source, collecting-grounds, and works, which should be periodic, systematic, continuous; and

(*c*) Chemical and bacteriological examination of samples of the water taken from various points of the system, at regular, short, intervals.

Under the first head, would be included not only amount, quality as to hardness or softness and power of plumbo-solvent action, but also the fauna and flora of the water. When such data are known any alterative additions may the more easily be detected in the subsequent periodic examinations. The appearance of certain, low, vegetable forms of life afford indices of change. Berlin, for example, had to abandon the water from wells sunk near the Tegeler Lake by reason of the development of *Crenothrix;* and the integrity of the Rotterdam supply was imperilled for some time for the same reason. This vegetable organism best thrives in the presence of organic matter and protoxide of iron, and it imparts to a water a disagreeable odour and taste. The unexpected presence of *Beggiatoa alba* in an Irish water-supply, rendering as it did the water turbid, was found to be due to decomposing water plants in the reservoir. Mez [1] in his work on the microscopic examination of water has done much to give insight into the import of the presence of such organisms.

Under the second head, it may be said that however intimate may be the character of the examination of water, ocular inspection of the sources of supply cannot be omitted. By it the grosser forms of pollution may be detected in their inception. There can be no reasonable doubt that if systematic inspection of the gathering-

[1] *Mikroskopische Wasseranalyse*, Berlin, 1898.

grounds of many of the supplies which have given rise to epidemics of enteric fever had been in operation, such would either have altogether been prevented, or the effects of pollution at least minimised. It is only necessary to quote from the report of Mr. Percy Adams regarding the cause of the Maidstone epidemic to show this. In speaking of the condition of the springs from which the supply came, he said that one of them was situated "about 50 yards from a privy which, at the time of our visit, was in a disgraceful condition, a large deposit of fæces decomposing and flooding the ground with its constituents, and in too close proximity to the very superficial source or gathering-ground; and, taking into consideration the very heavy rainfall in August [the epidemic began in September], must have been very widely distributed over the surrounding area." Again, in 1898 attention was called to the conditions of the water-supply of Aberdeen, which is taken from the river Dee. Upon investigation it was found that a spout of sewage was entering the aqueduct at the rate of about 700 gallons per day, and, in addition, within 10 feet of the aqueduct, there was a cesspool and an area of sewage-saturated soil. In like manner, may be discovered manurial contamination from arable land, carcases of dead animals, and other gross pollutants. Such inspection, therefore, must be regular, systematic, and especially in the case of deep wells and springs, minute.

Chemical Analysis and Bacteriological Examination are both demanded in the examination of potable waters. They are complementary of each other. Chemical methods have their limitations, hence they ought to be supplemented by bacteriological methods; the former can perfectly detect inorganic substances suspended or dissolved in water, but opinion derived from them in respect of organic matters is as likely to be wrong as right. This must be considered as having special bearing upon individual analyses; it does not apply so forcibly when systematic analyses at short stated intervals cover a long period. If we start from the fact that water-borne diseases are microbic in causation, the need for determining the presence or absence of specific organisms becomes not only evident but urgent. Their detection may be difficult, but it is none the less desirable. In all cases, therefore, where the original source of supply is liable, or is actually known to be contaminated, bacterioscopic investigation cannot be neglected, but should continuously be employed for testing the efficiency of filtration. A well-defined plan and exactness of method of bacteriological examination of water should now be formulated, as has been done for chemical examination. A committee of bacteriologists was appointed by the American Public Health Association to formulate such a scheme of examination, and they reported in 1898 that certain tests should be applied to all micro-organisms found in water, viz.: (1) Source and Habitat; (2) Morphological characters; (3) Biological characters, with reference to (*a*) cultural characteristics, (*b*) biochemical features, and (*c*) pathogenesis. They further recommended the adoption of (1) uniformity of methods of preparation of culture media, and their range; (2) uniformity of reaction of media, according to a test scale detailed in the report; and of many other important points. Such a scheme and lines of uniform procedure might well be

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do not contain much more than about 500 parts of salts per 100,000, or 0·5 per cent.

The amount of salts in Usar or alkali land is usually stated in parts in 100 of soil, and it is found in practice that soils containing much more than 0·1 per cent. are infertile. Immediately after irrigation, such a soil would contain a solution of about 0·33 of salts per 100 of water, but after the lapse of a few days, the proportion of water decreases to 10 or 15 per cent., and in this state the above mentioned solution would become concentrated to about 1·0 or 0·66 per cent. respectively. These figures correspond practically with what is known about the well waters.

DISCUSSION.

Mr. J. SPILLER said that in the year 1865 he had occasion to examine some remarkable products obtained from a highly saline spring which discharged itself into Lake Lohhar, India. The water left on evaporation 8·25 per cent. of solid residue, which consisted roughly of two parts of common salt to one of sodium carbonate. A local attempt at a separation of these resulted in a purified product, which had the following composition :—

Sodium carbonate	75·0
,, chloride	0·6
Calcium carbonate	1·9
Sand and ferric oxide	2·7
Water, nearly	20·0

There was no sulphate, bromide, borate, or nitrate.

*84. "Nitrobromo-derivatives of fluorescein." By J. T. Hewitt and A. W. G. Woodforde.

The non-fluorescence of alkaline solutions of nitro-derivatives of fluorescein was explained by the assumption that the alkaline salts of orthonitrophenols have the metal attached to the nitroxyl and not to the hydroxyl group (Hewitt and Perkins, *Trans.*, 1900, 77, 1324). With regard to the position of the nitro-groups in dinitrofluorescein, it was assumed that these occupied positions 2 and 7. (The numbering of the fluoran ring corresponds to Richter's numbering in the xanthene nucleus.)

Additional support was lent to this view by the isolation from the product of alkaline fusion of a small amount of material having a melting point of 114°. Since 4-nitroresorcin melts at 115°, the substances were supposed to be identical, and hence positions 2 and 7 were assigned to the nitro-groups in the fluoran nucleus. It is now shown,

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in diameter, with a slot one inch in breadth, the sides of the slot, and the bottom of the cylinder being each sharpened to a cutting edge. The worm auger was only used for exploring the subsoil to some depth. The auger was undoubtedly most useful for securing a fair sample, especially in field work, where one did not want to be burdened with a great weight of soil; but there were many soils on which it could not be used, they were either too hard, too stony, or too loose to remain in the tool. The steel box employed at Rothamsted could be made to give the most accurate results, but it was not wise to lay down any hard and fast rule as to which was the best tool. The analyst must examine the soil, and then use his judgment.

As to Dr. Leather's figures, not only did they support his opinion that fair samples could be drawn with the auger, but they showed that he must have been working with an extremely uniform soil, probably of alluvial origin. In England samples taken from adjoining fields on the same formation would vary between far wider limits than those shown by Dr. Leather's figures.

Dr. Leather, in reply, said that so far as stones are concerned, the determination of their amount would naturally demand that comparatively large portions of soil should be taken, but this consideration would not apply to the examination of the fine earth. Of the Indian soils examined, that at Cawnpore is alluvial, but the geological history of the Poona land is uncertain.

*83. "Some excessively saline Indian well waters." By J. W. Leather.

The composition of some well waters from the Muttra District, United Provinces, India, was given in detail. These waters contain from 200 to 2000 parts of salt per 100,000 of water. About one-half of the saline matter consists of sodium chloride; the amount of carbonate is about 20 to 30 parts; the nitrate varies from nothing to 250 parts; very large amounts of sulphate were present in some of the samples. In three cases, there was an excess of lime over that required to combine with the nitric, carbonic, and sulphuric acids, thus proving the presence of calcium chloride.

Some of these waters are used for irrigating crops. The soil of the district is open, the drainage conditions are good, and no salts accumulate in the surface soil. These waters provide an indication therefore of the maximum strength of solutions in which plants can grow, a point which is of importance in connection with the alkali lands of America, and the Usar lands of India. It is found practically that, of these well waters, those may be employed for irrigating crops which

considered by bacteriologists in this country for bacteriological examinations of water, as were laid down by the Society of Public Analysts for chemical examination.

II. *The Supervisory Control on the part of the Consumers.*—Complaints have from time to time been made that owing to want of enforcement of their powers private water companies fail in their duty to the consumers to conserve the purity of their supplies; that local authorities, whose districts are supplied by water from such companies, have no executive powers in protecting their ratepayers against pollution of supply, have no right of entry to the gathering-grounds, reservoirs, or works, cannot take samples, and have no means of satisfying themselves that the area of reservoir storage is ample enough, or that the purification processes are efficient, or are efficiently used for supplying a pure water. It has been urged that if such powers were granted, the companies would be apter to enforce their powers against pollution, that epidemics of water-borne diseases would diminish in number, and that greater benefit would accrue to the public health. But it must be pointed out that private water companies are performing the duty which municipal or urban authorities might themselves have been, nay perhaps, ought to have been, performing all the time; and, further, that even now, a local authority, or a group of authorities, can relieve itself of its undesirable position by purchasing the undertaking from the company, under section 51 of the English Public Health Act, or under section 126 of the Act for Scotland. This depends, of course, upon a willing buyer and a willing seller, upon the desirability or undesirability of purchase of existing works, and upon other factors. But so long as the present position remains, right of reasonable access to water-works belonging to private companies ought to be possessed by local authorities of the areas of supply. This view has commended itself to the English Local Government Board which has drawn up certain clauses for future legislation as follows:—

Clauses Suggested by Local Government Board of England for the Protection of Sources of Water-Supply.

Penalty for Failure to Supply Pure and Wholesome Water (10 Vict. cap. 17).—1. If the company fail to provide and keep such a supply of pure and wholesome water as is required by section 35 of the Waterworks Clauses Act, 1847, they shall, unless prevented by frost, unusual drought, or other unavoidable cause or accident, be liable for the first offence to a penalty not exceeding £20, and to a penalty not exceeding £5 for every day on which the offence is continued after conviction; and such penalties may be recovered summarily before a Petty Sessional Court.

2. Any offence under this section may be prosecuted by any local authority acting in the execution of the Public Health Acts in any part of whose district the company supply water for domestic purposes.

3. All penalties recovered under this section shall be applied in such manner as the Court may direct.

Power to take Samples of Water.—1. For the better enforcement of the provisions of section 35 of the Waterworks Clauses Act, 1847, any medical officer of health or other person authorised by local authority, acting in the execution of the Public Health Acts for any districts in any part of which water is supplied by the company for domestic purposes (producing, if required, a certificate of his personal authority signed by the clerk to the local authority), shall be entitled at any time, on giving not less than six hours' notice to the company, to take and

carry away samples of water from any land, reservoir, work, building, filter-bed, main-pipe, stand-pipe, or stop-cock of the company from, through, or by which a supply of water is given, and may for that purpose enter upon any lands or premises of the company. Any person who obstructs or molests such medical officer of health or other person authorised as aforesaid, shall be liable to a penalty not exceeding £20 for each such offence; and such penalty may be recovered summarily before a Petty Sessional Court.

2. Any water consumer may at any time, on giving such notice as aforesaid, take and carry away samples of water from any land, reservoir, work, building, filter-bed, main-pipe, stand-pipe, or stop-cock of the company from, through, or by which a supply of water is given, and may for that purpose enter upon any lands or premises of the company.

3. Any samples shall be taken in triplicate, and shall forthwith be respectively sealed up and marked by the person taking the same, who shall leave one of such samples with the company, or an officer or other agent of the company, and may submit another for examination, if he thinks fit, and shall retain the third for future comparison if required.

4. The company shall be entitled to be represented by an officer or other agent when the samples are taken, sealed up, and marked.

5. For the purposes of this section "water consumer" means any person who is supplied by the company with water for domestic purposes, or who pays, or is liable to pay, any rate for such a supply.

Pollution of Sources of Supply.—1. For the better discovery of any pollution of the water obtained or supplied by the company, any officer of the company authorised in that behalf by the company, and any medical officer of health for any district whereof any part is supplied by the company with water for domestic purposes, authorised in that behalf by the local authority for such district, may at any time between the hours of nine in the forenoon and four in the afternoon, on producing, if required so to do, a certificate of his personal authority signed by the secretary of the company in the case of an officer of the company, or by the clerk to the local authority in the case of the medical officer of health, enter on any lands or premises from which the water is obtained or supplied, whether immediately or otherwise by the company, and may take and carry away samples of any water or of any matter, substance, or liquid which may appear likely to cause pollution to the water of the company, or whereby such water may be fouled.

2. Any samples shall be taken in triplicate, and shall forthwith be respectively sealed up and marked by the person taking the same, who shall leave one of the samples with the person having custody of the premises, and may submit another for examination, if he thinks fit, and shall retain the third for future comparison if required.

Power to enter Lands and Premises for the purpose of taking Samples and Discovering Causes of Pollution.—1. If any water consumer, authorised by section 2, or any person authorised by or under section 3, to take and carry away samples or to enter on any lands or premises is refused permission so to do, any justice having jurisdiction in the place where the land or premises is or are situate, on complaint thereof on oath by such person (made after reasonable notice in writing of the intention to make the same has been given to the person having custody of the premises) may, on reasonable cause being shown, by order, require such person to admit the person authorised as aforesaid upon the premises during the hours mentioned in the order, and to permit and give all facilities to him to take and carry away such samples as aforesaid.

2. Any order made under this section shall continue in force until the purposes for which such order was made are completed; and any person who refuses to obey an order so made shall be liable to a penalty not exceeding £5 for each such offence, such penalties to be recovered summarily before a Petty Sessional Court.

Examination of Water as to Purity.—The complete examination of a water involves different lines of inquiry, viz.:—

(*a*) Physical characters;
(*b*) Chemical characters;
(*c*) Biological or bacteriological characters.

The physical examination includes (*a*) the presence or absence of suspended matters; (*b*) colour; (*c*) taste; (*d*) odour; (*e*) amount of dissolved gases.

Suspended matters may be discovered by holding a clear glass vessel containing the water between the eye and a good light. To establish their character, they should be allowed to subside in a conical-shaped vessel, pipetted off, and examined microscopically by dotting a series of slides with the deposit. They may consist of (*a*) mineral matters; (*b*) vegetable débris or algæ; (*c*) animal débris. The amount per gallon may be estimated by filtering a given quantity of water through a tared filter, drying, and weighing, and the amounts of mineral and organic matter respectively by igniting the deposit and filter-paper, the difference in weight, minus the ash of filter-paper, being the amount of organic matter, the remainder being the mineral.

Colour is best compared against an equal column of distilled water. For this purpose, equal quantities of the water and distilled water are put in 2-foot long tubes with ground-glass bottoms, and the observer looks down the columns of water which are held close together against a white surface. By this means, very slight differences may be detected. All potable waters have some measure of colour compared with distilled water. They vary from bluish to yellowish or brown; the former in chalky, the latter in peaty, waters. A greenish hue is, upon rare occasions, observed in waters, the sources of which are infested with pond-weed, and is due to chlorophyll. Water of a reddish tint betokens iron, which is corroborated by the deposit of the reddish-yellow oxide on the sides and bottom of the original vessel, and at the source.

Taste.—Good, well-aërated water is palatable, does not possess any distinct taste, but does possess something which the sense of taste distinguishes at once from a "boiled" water. Palatability may be possessed, however, by an impure water. This palatability seems to depend largely upon the contained atmospheric gases. Actual taste may be imparted to a water by contamination by odorous substances, or by the presence of excess of mineral salts. Short of mineral waters which possess distinct taste, potable waters may possess an unusual amount of mineral salts. Iron existent in quantity to one-fifth grain per gallon imparts a taste; lime salts, when in quantities of 10 to 25 grains; and sodium chloride, of 75 grains. The presence of certain vegetable organisms, as *Crenothrix*, imparts a bitter taste.

Odour.—Good water has no smell. Certain mineral waters containing sulphur gases possess a disagreeable odour due to H_2S. Ordinary potable water seldom possesses any odour, except when much polluted by fæcal matter, by coal gas, or by other odorous substance, as paraffin products. We have detected both of these last in waters analysed by us. The most efficient way to detect odour is to warm the water in a corked flask, and then by sniffing on removal of the stopper. No water is potable which has a perceptible odour.

Amount of dissolved gases.—This investigation is carried out by special apparatus. A well-aërated water contains atmospheric gases to the extent of 20·73 c.c. volumes per litre. The gas which in polluted water shows reduction is oxygen.

(B) Chemical Examination.—For sanitary purposes this resolves itself into examination for (*a*) mineral constituents; (*b*) hardness; (*c*) chlorides; (*d*) ammonia, free and albuminoid; (*e*) nitrates and nitrites; (*f*) organic matter.

A.—Mineral Constituents.

(*a*) Lime—*Quantitative.*—A definite quantity of water being taken (250 c.c.), ammonia and powdered crystals of ammonium oxalate are added by stirring. After some hours, the precipitate is filtered, washed, dried, weighed, and ignited, and the residue weighed as calcium carbonate. The amount found, counted as milligrammes and multiplied by 4, will give parts per million.

Qualitative.—The reagents are the same. They will give a distinct turbidity when lime is present to the extent of 8 parts per 100,000, or 5 grains per gallon.

(*b*) MAGNESIA—*Quantitative.*—The filtrate from the lime estimation may be concentrated by boiling, after which sodium phosphate, ammonium chloride, and excess of ammonia are added, and the solution freely stirred. After standing for 24 hours, the crystalline ppt. of ammonium-magnesium-phosphate (NH_4MgPO_4) is filtered, the ppt. washed with ammonia and water from a wash-bottle, then dried, ignited, and the residue weighed as magnesium pyrophosphate ($(MgO_2)P_2O_5$. The triple phosphate being soluble to some extent in water, it is customary to add 1 milligramme for every 50 c.c. of washings.

Qualitative.—The reagents are the same.

(*c*) IRON—*Quantitative.*—This is best estimated colorimetrically. Reagents necessary: (1) A standard solution, made up of 4·96 grammes of ferrous-sulphate per litre, of which 1 c.c. is equivalent to 1 milligramme of iron; (2) Solution of potassium sulphocyanide, 5 grammes in 100 c.c. distilled water; (3) Nitric acid, 30 c.c. strong acid to 100 c.c. distilled water. Into Nessler glasses place an equal quantity of (*a*) water-sample, and (*b*) distilled water respectively; to (*a*) add 5 c.c. of Nitric Acid solution, to oxidise ferrous into ferric iron, and then add 15 c.c. of solution of potassium sulphocyanide. If iron be present, a beautiful rose colour will develop. Into the glass (*b*) put one or more c.c. of the standard iron solution, with equal quantities of the other reagents as in (*a*), until the colours are exactly matched; that is, until they contain equal quantities of iron. Since it is known what amount has been added, calculation will show amount present per 100,000 parts of water.

Qualitative.—Ammonium sulphide causes the water to become of a darker colour, due to iron sulphide, but this disappears on addition of some drops of dilute HCl.

(*d*) LEAD—*Quantitative.*—This may be estimated colorimetrically. Reagents necessary:—(1) A standard solution of lead nitrate or acetate, made by dissolving 1·6 of nitrate or 0·1831 grammes of acetate per litre of freshly distilled water, of which 1 c.c. is equivalent to one milligramme of lead; (2) Clear sulphuretted hydrogen water. Equal quantities of water-sample and distilled water are placed
each
in Nessler glasses, and 1 c.c. of H_2S water added to sample. If lead be present the water will become darkened (seen by looking through column of water against a white ground). This colour must be matched in the other glass by adding sufficient standard lead solution, but the same amount only of the other reagent as in the former glass. Calculation will bring out parts per 100,000, or in any other proportion.

Qualitative.—H_2S gives the same reaction qualitatively, the colour being unchanged on addition of dilute HCl, but the chloride is thrown down, which dissolves on boiling the mixture. Solution of chromate of potash gives a faint yellow turbidity in presence of minute quantities of lead.

(*e*) COPPER—*Qualitative.*—This is a rare constituent of natural waters. If suspected, however, a few drops of Ammonium Sulphide should be added. If, on addition of dilute HCl, the dark colour does not disappear, it may be due to either lead or copper. To a fresh part of water, and after addition of NH_4HS, add solution of potassium cyanide; if copper, the dark colour will disappear.

Quantitative.—If copper be found qualitatively, it may be estimated quantitatively as for iron or lead, by using a standard solution of copper sulphate, made by dissolving 3·93 grammes of that salt per litre of water, of which 1 c.c. is equivalent to 1 milligramme of copper.

(*f*) ZINC.—Is sometimes found in waters after standing for some time in galvanised vessels, or in those collected from zinc-galvanised roofs. Such have been recorded from Llanelly, Wales, the Malay Peninsula, and other places. In the latter-named place, the quantity of zinc found amounted to 1·115 parts per 100,000, and in the former to about 70 parts per 100,000. Add nitric acid; boil; filter. To filtrate add potassium *ferrocyanide* solution, when, if zinc is present, a haze or turbidity will develop.

(*g*) SULPHATES (as SULPHURIC ACID).—Such are found in hard waters in combination with lime and magnesia.

Qualitative.—If to a sample of water, on addition of dilute HCl and a solution of barium chloride, a white haze or turbidity or ppt. appears, the presence of sulphates is indicated. This test will detect 2 to 3 grains per gallon, or 4 parts per 100,000.

Quantitative.—If the same reagents in excess be added to 250 c.c. of sample

with free stirring, and the ppt. allowed to settle, then filtered, washed, dried, ignited, and weighed, the amount in parts per 100,000 may be calculated from the weight of the $BaSO_4$.

(*h*) SULPHIDES (as H_2S)—*Qualitative.*—(1) A solution of lead acetate gives a darkened colour to the column of water of PbS ;

(2) A solution of copper sulphate gives a like result of CuS ;

(3) If a few drops of dilute caustic soda (NaHO) be added to water-sample, followed by an equal quantity of a solution of Nitro-prusside of sodium, a violet coloration is produced. This test detects minute quantities.

(*i*) CHLORIDES (as CHLORINE).—The purity of waters being in some degree estimated from the quantity of chlorides found, this test is of importance.

Qualitative.—If on addition to the water-sample of dilute nitric acid and a solution of silver nitrate a haze, turbidity, or ppt. result, chlorides are present. One grain per gallon gives a decided haze, four grains, marked turbidity ; or 1·5 and 5·7 parts per 100,000, respectively.

Quantitative.—Solutions necessary : (1) A standard solution of silver nitrate, made by dissolving 4·788 grammes of that salt per litre of distilled water, of which 1 c.c. is equivalent to 1 mgrm. of *Chlorine;* (2) a saturated solution of potassium chromate, made chlorine-free by addition of silver nitrate until a ppt. of silver chromate is permanently formed. On decanting the clear yellow solution, it is ready for use. 100 c.c. of water-sample are placed in a wide-mouthed flask standing on a white surface, two drops of potassium chromate solution are added, and from a burette the standard silver solution is added slowly in drops, with continuous rotatory movement of the flask, until the silver chromate ceases to be dissolved, and a faint *reddish* tinge is imparted to the fluid in the flask. The number of c.c. of silver solution used equals the parts per 100,000 of the chlorine present. By multiplying the figure found by 0·7, the equivalent in terms of grains per gallon is found.

(*j*) NITRATES—*Qualitative.*—*a.* To water-sample in test-tube add some strong H_2SO_4, and a few drops of a solution of *diphenylamine* in H_2SO_4. If a blue colour be struck, nitrates are present.

b. Evaporate to dryness in porcelain capsule 25 c.c. of sample ; add two drops of strong H_2SO_4, and a granule of brucine, and a rose colour, becoming rainbow-like, will appear. This test detects one part in a million of water.

Quantitative.—Reagents necessary : (1) Solution of phenolsulphonic acid, made by dissolving together 6 grammes pure carbolic acid, 37 c.c. strong H_2SO_4, and 3 c.c. distilled water; (2) standard solution of potassium nitrate, made by dissolving 0·722 gramme of the pure fused salt per litre of distilled water, of which 1 c.c. is equivalent to 0·1 mgrm. of *nitrogen.*

Process.—Evaporate to dryness 10 c.c. or more of the sample ; add 1 c.c. of phenolsulphonic acid ; mix with residue with glass rod, then add 1 c.c. distilled water, and 3 drops of strong sulphuric acid ; warm on water-bath ; then add 25 c.c. distilled water. Put solution in a Nessler glass, and fill up to zero-mark with dilute clear caustic potash solution. The yellow colour present is due to potassium picrate.

Treat 1 c.c. or 2 c.c. or more of the standard nitrate solution in exactly the same way, and compare the colours produced. When the colours are matched, calculation from the quantity of standard nitrate added to the parallel test-glass will show the parts of nitrogen present per 100,000 parts of water.

(*k*) NITRITES—*Qualitative.*—*a.* If a solution of zinc-iodide-starch solution and dilute H_2SO_4 be added to sample, and a blue coloration develop (best seen looking through water column against white ground), nitrites are present, according to the equation—

$$ZnI_2+2KNO_2+2H_2SO_4=I_2+ZnSO_4+K_2SO_4+2NO+2H_2O.$$

On addition of the acid, nitrous acid is liberated from its combination, which in turn dissociates the iodine from the zinc, and renders it free. The free iodine unites with the starch to form the blue iodide of starch. This test can detect one part in fifty millions of water.

b. On addition of an acetic acid solution of sulphanilic acid and naphthylamine acetate solution, a beautiful pink colour appears, but only slowly if quantity of nitrites be small.

Quantitative.—Reagents required : (1) Solution of sulphanilic acid, made by

dissolving 0·5 gramme of the acid in 150 c.c. of dilute acetic acid (sp. gr. 1040); (2) solution of naphthylamine acetate, made by boiling 0·1 gramme of solid naphthylamine in 20 c.c. distilled water, filtering through a plug of washed cotton-wool, and mixing filtrate with 180 c.c. of dilute acetic acid (as above); (3) standard solution of sodium nitrite, made by dissolving 0·275 gramme of pure silver nitrite in distilled water, and then adding a dilute solution of pure sodium chloride until the ppt. of silver chloride ceases to fall. Add up to 250 c.c. with distilled water. The solution contains per c.c. 0·1 mgrm. of nitrogen as sodium nitrite. For use, 10 c.c. of this solution are diluted to 100 c.c. with distilled water, and 1 c.c. of this now contains 0·01 mgrm. of nitrogen. These solutions must be kept in the dark when not in use, and in dark glass bottles.

Process.—25 c.c. or 50 c c. of sample are placed in a Nessler glass, and to it are successively added 2 c.c. of solutions (1) and (2) by means of different pipettes. The pink colour which appears must be exactly matched. Into another Nessler glass are placed an equal quantity of distilled water, 1 or more c.c. of the standard nitrite solution (3), and quantities of the reagents similar to those in the other glass. When the colours are matched, the number of parts of nitrogen as nitrites per 100,000 parts of sample may be calculated from the data which have been found.

(*l*) COMBINED NITROGEN IN NITRATES AND NITRITES, ETC.—The total quantity of nitrogen, as nitrates and nitrites, may be estimated by the copper-zinc couple process. Zinc foil is coated black with copper by galvanic action on being placed in a solution of copper sulphate containing 1·8 per cent., and is then carefully washed with distilled water. The couple, as it is then called, is put into a wide-mouthed glass-stoppered bottle with 250 c.c. of the water-sample, to which has been added 0·5 gramme of finely powdered oxalic acid. The bottle, stoppered, is placed in a warm place for twenty-four hours. The couple acts by electrolysis on the water, liberating hydrogen and splitting up the combined nitrogen; and these uniting together form ammonia, which is estimated by direct Nesslerising (*q.v.*) after filtering, to rid the water of any lime oxalate which may have been precipitated. The combined nitrogen is, thereafter, estimated by this process in terms of ammonia.

(*m*) PHOSPHATES—*Qualitative.*—Add some dilute HNO_3 to 250 c.c. water-sample, and evaporate to dryness. Heat residue cautiously, dissolve in dilute HNO_3, and filter. To clear filtrate, add twice the volume of warmed, strong solution of ammonium molybdate. The formation of a yellow colour or turbidity indicates phosphates, as ammonium phospho-molybdate.

Since it is but the very rarest occurrence that phosphates are present in more than traces, quantitative examination is usually unnecessary.

(*n*) HARDNESS—*a.* Soap Method.

Quantitative—Reagents required : (1) Standard soap-solution, made by dissolving 10 grammes of finely-powdered Castile soap in a litre of 35 per cent. alcohol; (2) Standard solution of lime, made by dissolving 1·11 grammes of pure calcium chloride in a litre of distilled water, of which 1 c.c. is equivalent to 1 milligramme of $CaCO_3$. It is necessary to standardise the soap-solution against standard lime solution, so that 1 c.c. of it will be equal to 1 c.c. of the other. To do this, 5 c.c. or 10 c.c. of the standard lime solution should be diluted to 100 c.c. with distilled water, put into a glass-stoppered bottle, and the standard soap solution from a burette added in small quantities at a time, with vigorous shaking of bottle and contents after each addition, until a uniform, creamy lather is formed which will remain unbroken for 5 minutes when the bottle is laid on its side. If the number of c.c. of soap solution added be 6·5—where 5 c.c. of standard lime solution has been used—or 11·5 where 10 c.c., then the soap solution is right, since 1·5 c.c. of it is required for the distilled water alone. If, however, less be necessary, then it is too strong, and it must be diluted with the necessary amount of weak alcohol, the precise number of c.c. to be added being calculated from the mean of three titrations. As soap solution decomposes on keeping, it is necessary to titrate it against the standard lime solution from time to time, so as to know its valency.

Let it be assumed that 1 c.c. of the soap solution is equal to 1 c.c. of the standard lime solution, then the process of testing the water-sample is as follows:—

Into a glass-stoppered bottle put 100 c.c. of water-sample; from a burette, add the soap solution in quantities of 1 c.c. at a time, shake vigorously after each

addition, until a lather of the kind and persistency described above is formed. Repeat the process a second time, adding the soap solution more boldly till the lathering point is neared, and then only drop by drop, for exact estimation. The number of c.c. of soap solution used by 100 c.c. of water-sample, less 1·5 c.c., is the measure of hardness in terms of $CaCO_3$ per 100,000 parts. Thus: Suppose 12·5 c.c. of soap-solution are used by 100 c.c. of water (1 c.c. = 1000 milligrammes), then 12·5 – 1·5 c.c. = 11 parts of $CaCO_3$ per 100,000 parts of water.

The foregoing estimation is of the *total hardness*. To estimate the *temporary* hardness, 100 c.c. of sample are boiled for twenty minutes in a flask and then filtered, and the quantity less than 100 c.c. lost by evaporation, is made up to that figure by the addition of distilled water. Since boiling drives off CO_2 and thereby throws down the carbonates of lime and magnesia, the hardness due to these salts is now removed. Titration of the water now, performed as above, gives the permanent hardness. Suppose 6·0 c.c. of soap-solution were now required, then 6 – 1·5 = 4·5 = parts of *permanent* hardness per 100,000. To ascertain the *temporary* hardness, it is only necessary to deduct the figure for the permanent hardness from that of the gross total hardness, and 1·5 from the product, thus:—

$$(12{\cdot}5 - 4{\cdot}5) - 1{\cdot}5 = \underline{6{\cdot}5} \text{ parts temporary hardness per 100,000 parts of sample.}$$

b. Chemical Method.

Reagents required: (1) $\frac{N}{50}$ solution of pure Sodium Carbonate, made by dissolving 1·06 grammes of the pure salt in one litre of distilled water, of which 1 c.c. contain ·00106 gramme Na_2CO_3, and is equivalent to ·001 gramme or 1 mgrm. of $CaCO_3$; (2) $\frac{N}{50}$ solution of Sulphuric Acid, of which 1 c.c. is equivalent to 1 c.c. of $\frac{N}{50}$ Na_2CO_3; (3) solution of methyl-orange (as indicator).

Process—a. Temporary Hardness.—To 250 c.c. of water-sample add two drops of indicator, and heat to boiling. From burette, filled with $\frac{N}{50}$ H_2SO_4, add drop by drop (shaking flask constantly) until yellow colour changes to pink. Since each c.c. of $\frac{N}{50}$ acid used is equivalent to 1 mgrm. of $CaCO_3$, from the number of c.c. used, the quantity of $CaCO_3$ present may be calculated.

b. Permanent Hardness.—To 100 c.c. of sample, add slight excess of $\frac{N}{50}$ of Na_2CO_3 (usually equal parts will be sufficient); evaporate mixture to dryness in platinum vessel; extract residue with distilled water; filter solution through small filter-paper and wash well the deposit on filter with hot distilled water; titrate combined filtrate and washings with $\frac{N}{50}$ acid after addition of two drops of indicator. The difference in number of c.c. of $\frac{N}{50}$ Na_2CO_3 originally added to sample and the number of c.c. of $\frac{N}{50}$ acid required to neutralise the solution equals the measure of the permanent hardness in amount of sample treated. By easy calculation, the amount in parts per 100,000 of permanent hardness, in terms of $CaCO_3$, may be found.

Rationale.—The addition of the $\frac{N}{50}$ alkali to sample decomposes Sulphates, Chlorides, and Nitrates of Lime and Magnesia, and liberates the corresponding acids by forming carbonates with the bases which were combined with the acids named.

Note.—If the original sample be alkaline from presence of Na_2CO_3, K_2CO_3, or both, there will be no permanent hardness, and if titration has been carefully performed, more $\frac{N}{50}$ acid will be required in titration of filtrate than the amount of $\frac{N}{50}$ alkali added initially to water-sample. The difference in excess equals the amount of alkaline carbonates natively present in water-sample. In such a case, therefore, to obtain the true temporary hardness, it is necessary to deduct the

excess in this process from the result obtained in the estimation of temporary hardness.

(*o*) AMMONIA—*Qualitative*.—If two or three drops of Nessler's solution be added to a column of water in a Nessler glass or long test-tube, and a yellow or yellowish-brown colour be formed, ammonia is indicated. This test detects minute quantities.

Quantitative (Wanklyn's Process).—Reagents required: (1) Standard solution of ammonium chloride, made by dissolving 0·382 gramme of pure dry ammonium chloride in a litre of distilled, ammonia-free water, of which 1 c.c. is equivalent to 0·1 mgrm. of ammonia; (2) a weaker standard solution, made by making up 100 c.c. of the above to one litre with distilled, ammonia-free water, of which 1 c.c. is equivalent to 0·01 mgrm. of ammonia; (3) Nessler's reagent, made by dissolving 15 grammes of potassium iodide, 17 grammes of mercuric chloride, and 160 grammes of caustic potash in a litre of distilled, ammonia-free water. If a permanent precipitate be not formed, sufficient mercuric chloride solution (saturated) must be added until it is formed. The reagent is then sensitive for use. (4) Alkaline permanganate solution, made by dissolving 8 grammes of potassium permanganate and 200 grammes of solid caustic potash in a litre of distilled water. After solution of ingredients, the mixture should be boiled until one-third of the bulk is evaporated. After the mixture is cooled, the total bulk is made up to one litre by the addition of ammonia-free water. This ensures the freedom of the reagent from ammonia. (5) Distilled ammonia-free water.

The ammonia in a water is estimated as *Free* or *Saline* and as *Albuminoid* ammonia, the latter being a measure of the nitrogen contained in more or less complex albuminoid compounds in a water, and which is converted into ammonia by the action of the alkaline permanganate solution.

The estimation of the ammonia in this process is colorimetric, and is made in the distillates obtained from the water by distillation, the process of colorimetric estimation being known as "Nesslerising."

The following apparatus is required: (*a*) a boiling flask; (*b*) a Liebig's condenser, fitted with an adapter; (*c*) 1 c.c. and 2 c.c. pipettes; (*d*) Nessler glasses, graduated at 50 c.c. and 100 c.c., or Hehner's glasses, graduated in ½ and 1 c.c. up to 100 c.c., and fitted with glass stop-cock; (*e*) capillary glass tubes.

FREE OR SALINE AMMONIA—*Process*.—Half a litre of water-sample is placed in the cleaned boiling-flask, a pinch of freshly-ignited sodium carbonate (to make the water decidedly alkaline) is added, the flask is connected tightly with the Liebig's condenser, and the contents of the flask are heated to brisk boiling by a Bunsen burner. The distillate is collected in Nessler glasses, 50 c.c. or 100 c.c. at a time, until 200 c.c. have been distilled over. These distillates are reserved for Nesslerising. They contain the *Free* or *Saline* Ammonia.

ALBUMINOID AMMONIA.—To the 300 c.c. of water left in the boiling-flask are added 50 c.c. of the alkaline permanganate solution, and, in order to prevent "bumping" of flask and contents during subsequent boiling, some glass capillary tubes sealed at one end in the flame. The apparatus is again connected, and boiling resumed until 200 c.c. are distilled over, in which is contained the *albuminoid* ammonia. This, like the former distillate, is collected in 50 c.c. or 100 c.c. Nessler glasses for Nesslerising.

Nesslerising—Free Ammonia.—A Nessler glass containing the *first* distillate of 100 c.c. is placed on a large, white porcelain tile. To it are added 2 c.c. of Nessler solution by means of a pipette, and the whole is stirred by a clean glass rod. After 5 minutes the colour produced is observed, as the object is to match exactly the colour in another like-sized Nessler glass. Into a second glass, therefore, is pipetted 1 c.c., 2 c.c. or more of the weak standard ammonia solution (2), the glass filled up to the 100 c.c. mark with ammonia-free water (5), and 2 c.c. of Nessler reagent added by pipette. If the quantities of ammonia in each glass be similar in amount the colours produced will be identical; if not, then the colour of one or the other will be darker, depending upon which contains the larger quantity of ammonia: in which case, the object being to match the colour of the distillate, smaller or larger quantities of the weak standard ammonia must be made up with fresh ammonia-free water until the colours are exactly matched. When that is attained, it is known that the quantity of ammonia present in the distillate is equal to that added in the parallel glass.

The second 100 c.c. of distillate is Nesslerised in the same way, and the sum of the two is the amount of Free Ammonia in 500 c.c. of water-sample.

The distillate containing the albuminoid ammonia is then similarly dealt with and the amount of ammonia estimated in like manner.

Example.—Colours were matched in first 100 c.c. of distillate of *free* ammonia by 2 c.c. of standard ammonia solution (*b*), of which 1 c.c. = ·01 mgrm. ammonia; and in second 100 c.c. by 1 c.c.; therefore $\cdot01 \times 2 + \cdot01 \times 1 = \cdot03$ mgrms. of ammonia in 500 c.c., or 500,000 mgrms. of water; or $\cdot03 \times 2 = \cdot06$ in 1000 c.c. or 1,000,000 parts; or ·006 parts per 100,000 of water.

Albuminoid Ammonia.—Colours were matched in first 100 c.c. of distillate by 5 c.c. of ammonia solution; and in second 100 c.c. by 3 c.c.; therefore $\cdot01 \times 5 + \cdot01 \times 3 = \cdot08$ parts in 500 c.c. of water; or $\cdot08 \times 2 = \cdot16$ parts in 1000 c.c., or 1,000,000 parts; or ·016 in 100,000 parts.

In Nesslerising it is not a good plan to make additions of standard ammonia solution, to bring up the colour, after Nessler reagent has once been added, as the column becomes muddy and the colour difficult of comparison. It should also be noted that on rare occasions the colour in the distillate produced is difficult to compare, for reasons that are not well known. *It is very important that the water to be distilled should be alkaline, since acid waters will not give up their ammonia.*

To overcome the trouble of mixing different solutions to get the exact one to match the colours in the distillates, Hehner's glasses were devised. Suppose that the Nesslerising is done in two of such glasses, and that in one or other the colour is either darker or lighter, it is only necessary to run off the fluid from the darker until the colour is alike to that of the other. If, for example, the distillate be run down to 70 c.c. from 100 c.c. before the colours are equal, and if 2 c.c. of standard ammonia (2), have been added to the parallel glass, then obviously the quantity of ammonia in 100 c.c. of distillate is greater than in the other in the proportion of 70 to 100; therefore, $\cdot01 \times 2 \times \frac{10}{7} = \cdot0286$ mgrms. will be the quantity present in 100 c.c. of distillate. If, on the other hand, the colour in the parallel glass into which 2 c.c. of standard ammonia had been put was the darker, and that it had to be run down to 80 c.c. when the colours became equal; then, obviously, the quantity of ammonia present in the distillate will be less than it originally contained in the proportion of 100 to 80; therefore, $\cdot01 \times 2 \times \frac{8}{10} = \cdot016$ mgrms. is the amount of ammonia in 100 c.c. of distillate. This method is not only more expeditious, but is equally accurate so long as the liquid column is not run down lower than 50 c.c.

(*p*) ORGANIC MATTER—*Tidy-Forchammer Process.*—The organic matter is estimated in this process in terms of "oxygen consumed" in given periods of time, those commonly employed being twenty minutes and 3 hours respectively.

Quantitative—Reagents required: (1) standard solution of potassium permanganate, made by dissolving 0·395 gramme of that salt in a litre of freshly-distilled water, of which 10 c.c. is equivalent to 1 milligramme of available oxygen; (2) solution of sodium thiosulphate, made by dissolving ·5 gramme in a litre of distilled water; (3) solution of potassium iodide (free from iodate), made by dissolving 10 grammes in 100 c.c. distilled water; (4) starch solution, freshly made, composed of a filtered solution in which 10 parts of arrowroot starch have been boiled in 200 parts of water; (5) dilute sulphuric acid (1 part to 3 of distilled water) which remains slightly pink after addition of a few drops of potassium permanganate and after heating at 80° F., for 4 hours.

Apparatus required: (*a*) Flasks, with a capacity of 400 c c., four in number; (*b*) flat, open water-bath; (*c*) pipettes, 5 c.c. and 10 c.c.; thermometers.

Process.—Into each of two of the flasks put 250 c.c. of the water-sample, and into each of the other two, 250 c.c. of freshly-distilled water. *Note.*—The flasks must be *chemically clean* before being used. The four flasks are placed in the water-bath and the temperature regulated so that the water of the flasks during the experiment is uniformly maintained at about 80° F. Into each of the four flasks put 10 c.c. of permanganate solution (1), and 10 c.c. of sulphuric acid (4). Should the pink colour be discharged during the course of the experiment, another 10 c.c. of permanganate must be added; or a third if required, in the case of bad waters. At the end of twenty minutes, two of the flasks are removed from

the bath, and to each is added 2 c.c. of potassium iodide solution (3). As is the amount of permanganate unacted upon so is the amount of iodine which is liberated. In consequence of this change, the fluid in the flask which formerly was pink now becomes yellow. From a burette filled with sodium thiosulphate solution, a quantity is added sufficient to nearly discharge this yellow colour; then 2 c.c. of starch solution (4), are added, which strikes a blue or greenish-blue colour with the remaining free iodine; the addition of thiosulphate is then continued until the blue colour is just discharged. The number of c.c. of the thiosulphate used to produce this effect in the flask containing the distilled water is taken as the measure of the oxygen-value of 10 c.c. of standard permanganate, viz.: 1 mgrm. of oxygen, and the difference between the number of c.c. used in the distilled water and in the water-sample respectively is the measure of oxygen used up by the organic matter in the water-sample. For example: In twenty minutes, the number of c.c. of thiosulphate required for 250 c.c. of distilled water + 10 c.c. standard permanganate = 45 c.c.; number required for 250 c.c. of water-sample containing 10 c.c. of permanganate = 25 c.c. The former amount is equivalent to 10 c.c. of standard permanganate used, or 1 mgrm. of oxygen; the latter subtracted from the former is the measure of the amount of oxygen consumed in the water-sample. Therefore 45 c.c. − 25 c.c. = 20 c.c. The calculation, then, is as follows: $45 : 20 :: 1 : x$: $\therefore x = \cdot 4$ mgrm. Oxygen; that is, ·4 mgrm. of oxygen has been consumed in 250 c.c. of sample in twenty minutes. Since, however, only 250 c.c., or 250,000 mgrms. of water-sample have been used, the figure ·4 must be multiplied by *four* to bring out parts per million. Therefore $\cdot 4 \times 4 = 1{\cdot}7$ mgrms. of oxygen consumed per million parts of water, or ·17 parts per 100,000.

The other two flasks, which have been exposed for three hours, are similarly treated, and the result computed in the same way.

The object of the different periods of exposure is to differentiate the nature of the oxidisable matter. The period of twenty minutes indicates the amount of oxygen consumed in the oxidisation of chemical salts; that of three hours, the amount consumed in the oxidation of organic bodies of an albuminoid character.

The chemical equations of the different stages of the process are these:—

1. $4KMnO_4 + 6H_2SO_4 = 4MnSO_4 + 2K_2SO_4 + 6H_2O + 5O_2$;
2. $2KMnO_4 + 10KI + 8H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 5I_2$;
3. $2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6$;

By the addition of starch solution the blue or bluish-green iodide of starch is formed, which is discharged by further addition of Sodium Thiosulphate.

Opinion of Quality of Water from Chemical Analysis.—This opinion has reference to (1) purity, and (2) economical use. The constituents in a water, with reference to purity, to which close attention must be paid, are: amounts of (*a*) chlorides; (*b*) of ammonia, free and albuminoid; (*c*) of nitrates and nitrites; and (*d*) of oxidisable organic matter. In a water which is much polluted and has been for some time in that condition, abnormally high proportions of all these ingredients will likely be found. The source of the excess of chlorides is urine of sewage, and of ammonia, the decomposition of urea, while the nitrites and nitrates express progressive stages of oxidation of nitrogen from decomposed albuminoid bodies derived from sewage or vegetable albuminoid bodies, and the oxidisable organic matter may be taken as a gauge of the organic matter, liable to decomposition or oxidisation, which is present.

In order to institute comparisons, it is necessary to form a standard from the proportions of these, or some of these constituents which a pure water contains, in order to estimate which waters are impure, and what their relative impurity.

A pure water may be considered as containing the above ingredients in the following proportions, viz.:—

Chlorine	=	less than 1·4 parts per 100,000.
Free ammonia	=	·002 ,, ,,
Alb. ,,	=	·005 ,, ,,
Nitrogen {Nitrites, Nitrates}	=	·0025 ,, ,,
Oxygen consumed	=	less than 0·1 ,, ,,

A usable, or second-class water contains :—

Chlorine	=	less than 5 parts per 100,000.
Free ammonia	=	·005 ,, ,,
Alb. ,,	=	·010 ,, ,,
Nitrogen {Nitrites, Nitrates}	=	·125 ,, ,,
Oxygen consumed	=	·15 ,, ,,

A suspicious, or third-class water contains :—

Chlorine	=	more than 5 parts per 100,000.	
Free ammonia	=	,, ·005 ,, ,,	and less than ·025.
Alb. ,,	=	,, ·010 ,, ,,	
Total nitrogen (as above)	=	,, ·125 ,, ,,	and less than ·245 parts.
Oxygen consumed	=	,, ·15 ,, ,,	

An impure or dangerous water contains :—

Chlorine	=	from 7 to 10 parts per 100,000.
Ammonia {Free, Alb.}	=	,, ·0225 to ·025 parts per 100,000.
Nitrogen {Nitrites, Nitrates}	=	,, ·260 parts per 100,000 and upwards.
Oxygen consumed	=	,, ·20 ,, ,, ,, ,,

While it is true that these standards are arbitrary, they may be deemed as fairly accurate and representative of different classes of waters. It is very unsafe to pronounce an opinion unfavourable to the potability of a water from an abnormally high amount of any single ingredient, as, for example, chlorine, albuminoid ammonia, organic matter, or nitrates, for each of these when found alone is compatible with purity.

For example, while in any water, excess of chlorine to the amount of 15 to 18 parts per 100,000, would make the examiner suspicious of pollution, a low total of free and albuminoid ammonia, absence of nitrates, and low "oxygen consumed," would show that the excess of chlorine was due to some uncommon cause, which on inquiry would most likely prove to be proximity to the sea. We have several times had this experience. High albuminoid ammonia is a common feature of upland waters, and if a judgment was formed from this factor alone, it would likely be wide of the true mark, since its presence is accounted for by vegetable, peaty matter. Loch Katrine supply contains ·008 parts per 100,000 of albuminoid ammonia, but it has practically no free ammonia. In the same way, even with excess of chlorides and nitrates in a water, judgment would be liable to err if the fact is not known that such ingredients may be found in the waters of Artesian wells, regarding the sewage contamination of which there is no possibility. In forming an opinion upon the potability or purity of a water from chemical analysis only, careful scrutiny and comparison must therefore be made

of the different constituents which ordinarily indicate by their presence in excess sewage contamination, and from the relation of these to each other, a tentative opinion only should be offered. Before a definite, final opinion is given, exact information ought to be obtained regarding the source of supply of the water, and of its position and environment with respect to possible pollution.

Opinion as to Economical Use.—From what has been said, a hard water is less profitable and less suitable to a community than a soft water, and for the reasons formerly given. Where a new water-supply is proposed, of two waters, one hard and one soft, which are available, and where both are satisfactorily pure, the latter is preferable. Keeping

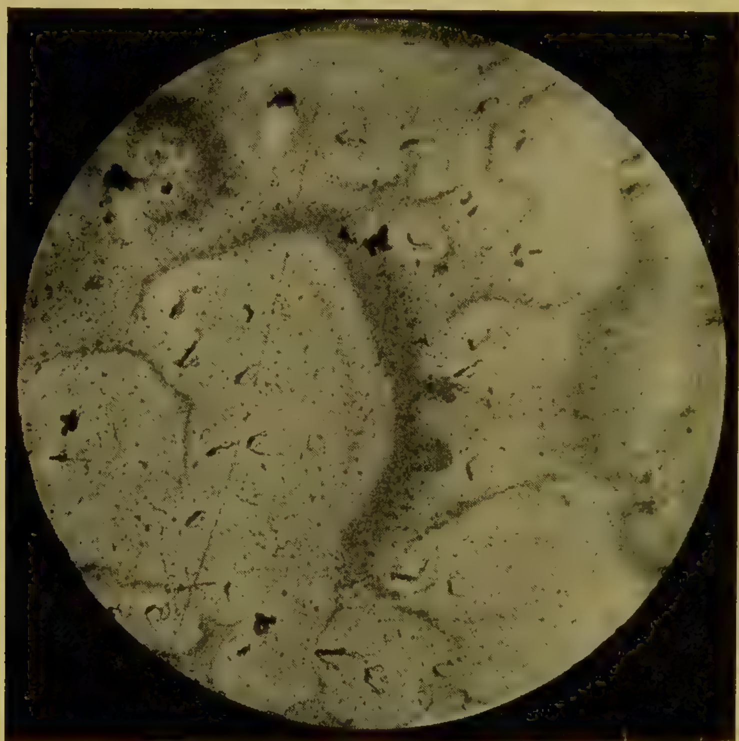


FIG. 156.—Photo-micrograph of *Spirillum Rubrum*—a not uncommon water micro-organism. ×500 diameters. (Author.)

the object in view for which the water is desired, a hard water may, however, be more useful than a soft water. This is particularly true, for example, of beer-brewing. Again, the presence or absence of suspended matter is of importance with reference to the need for filtration. Loch Katrine supply to Glasgow does not require filtration because of its freedom from matters in suspension. A river-supply, however, must needs be filtered because of the presence of suspended matters, and more especially because of the possible presence of the specific micro-organisms of disease.

Biological or Bacteriological Examination of Water.—The purity of any water may be also estimated from the number and kind of micro-organisms it contains per cubic centimetre. It may be held as

expressive of a general truth that the larger the number of micro-organisms present in that unit quantity of water, the more plentiful the amount of organic matter therein, and the greater the potentialities of risk to the consumer. But mere number of organisms per c.c. of water is by no means a safe, guiding index of risk in consumption, since the organic matter may be of vegetable and not of animal origin. Where, however, pollution by animal matter is possible, or indeed is likely, such a water would *a priori* be suspicious, because of the possibility of its containing specific organisms of disease, such as *B. typhosus*, *B. choleræ*, *B. enteritidis sporogenes*, *Amœba coli*, *B. coli communis*, and others. It is quite true that there is great difficulty in isolating these organisms, and chiefly the first two named, from a suspected water-supply, and less difficulty with the others; but so soon as *B. coli communis*, *B. enteritidis sporogenes*, or either of them is found in a potable water, its use becomes a positive danger, as sewage pollution is certainly betokened. Chemically pure waters contain but few organisms, but waters rich in organic matter contain them in abundance. Standards of purity of water may be based upon that and like facts. Miguel has proposed that waters should be divided into two classes, viz., pure and impure. Those waters ought to be deemed pure which contain less than 1000 microbes per c.c., those impure which contain over 1000 and under 100,000, and those to be very impure, more than 100,000 per c. centimetre.

To collect samples for bacteriological examination, small glass bulbs rendered vacuous, and drawn out to a fine extremity which is sealed, are convenient for use. Their sterilisation is effected by heat. The bulb is partially filled with water when the top of its capillary extremity is broken under water. When the operation is completed, the capillary point is sealed at a flame. If any time is to intervene between the sample-taking and the examination, each bulb should be placed separately in a tin with cotton-wool, and the tins surrounded by ice. Petri-plate cultures in gelatine and agar-agar should then be made with 0·1, 0·2, 0·5, and 1 c.c. respectively of the water, and after incubation at 22° C. and 37° C. for the gelatine and agar-agar respectively. The colonies which grow on these plates should be counted where the numbers can be counted, and the mean of the numbers found, calculated into 1 c.c., will represent the number of organisms, divided into moulds and micro-organisms, in 1 c.c. of the water-sample. Thereafter, pure cultures must be made of these colonies which are suspicious, so that by their cultural and morphological characteristics they may be identified. On these points, however, reference must be made to bacteriological works.

Law as to Water-supplies.—The following embraces the principal powers of local authorities with reference to water-supplies:—

I. *Law of England.*—It is embraced in the Public Health Act, 1875, and the Public Health Act, 1878, together with the Waterworks Clauses Act, 1847, and certain clauses of other Acts.

Briefly, then, it may be summarised as follows:—

Public Health Act, section 175, provides that any local authority may purchase, lease, sell, or exchange any lands within or without their district, and may buy up any water mill, weir, or dam which interferes with the water-supply of the district.

Note.—This purchase can be made either by voluntary arrangement, or by compulsion, in which latter case the Lands Clauses Consolidation Acts are incorporated in this Act, section 176, in which the course to be followed is set down. Difficulties regarding voluntary sale on the part of those vested in lands are overcome by the Lands Clauses Act, 1845, section 6, and the Settled Land Act, 1882, sections 3 and 58.

Up till 1894 the only body empowered to provide supplies in rural districts was the rural sanitary authority, but after the passing of the Local Government Act in that year, it was provided in section 8 that a Parish Council is empowered—only by agreement, however—to acquire any land and to legally utilise a water source for a water supply, and to contribute, wholly or partly, toward the cost of same.

Rural District Councils have full power to provide supplies for their parishes; proved failure on their part so to do, on complaint of the Parish Council to the County Council, may cause the power to be transferred to the County Council, which may itself, or, as in section 299, may appoint a person to carry through a scheme.

Section 51 enacts that the local authority may provide their district or part of it with water, and may construct, or lease, or hire, or purchase waterworks, or may contract with some one to provide a supply. Failure to do so, where the existing supply is insufficient or unwholesome, and where a proper supply may be obtained at a reasonable cost (sections 299–301), may be complained of to the Local Government Board, which may order the offending local authority to do its duty.

Section 64 enacts that all public water-supplies are vested in and under control of the local authority;

Section 70, that the local authority may close any source of water—public or private—which is proved to be polluted and therefore injurious to health, upon an order granted by the Court; and

Section 62 provides power to local authorities to enforce the supply of water to any house in a district where such is not supplied, but which may be supplied at reasonable cost; if the order be not obeyed, the local authority may itself perform the work and charge the cost, or may exact water rates. Section 3 of the Public Health Water Act, 1878, is to the same purport and defines "reasonable cost," and section 6 enacts that no new house shall be inhabited until it has been provided with an efficient water-supply which is available within reasonable distance.

The Waterworks Clauses Act, 1847, provides penalties against any one who pollutes a water-supply by bathing, clothes-washing, or by admitting sewage matter.

This may be taken, for our purpose, as a summary of the law relating to public water-supplies.

II. *Law of Scotland.*—It is embraced in the following Acts, viz.: The Public Health (Scotland) Act, 1897, sections 124 *et seq.*; the Burgh Police (Scotland) Act, 1892, sections 261–269 inclusive; Local Government (Scotland) Act, 1894; certain clauses of the Waterworks Clauses Acts, 1847 and 1863; the Railways Clauses Consolidation (Scotland) Act, 1845; and of the Lands Clauses Acts.

The Public Health Act of 1897, with respect to water-supplies, differs considerably from the Act of 1867. The latter Act dealt with both burghal and landward areas, whereas the former takes into account landward supplies only, since the Burgh Police Act of 1892 deals with the needs of burghs.

To all intents and purposes, for our present object, the law anent water-supply in Scotland may be taken as identical to that of England. Section 126 provides that the local authority may, if they think it expedient, "acquire and provide or arrange for a supply of water for the domestic use of the inhabitants and for sanitary or other purposes," and for that end may conduct water from any source, may dig wells, may purchase, lease, hire, construct, lay down, and maintain waterworks, the local authority to have the powers, rights, obligations, and responsibilities inherent to and imposed upon promoters of undertakings under the Lands Clauses Acts as amended by the Public Health Act, 1897. It is important to note that though the above section makes the duty on local authorities permissive, they are, nevertheless, liable, in the case of failure, to be proceeded against under section 147.

Section 126 enacts that all existing public cisterns, pumps, wells, reservoirs, etc., may be continued, maintained, and plentifully supplied with water, or may be substituted by other such works by the local authority;

Section 127 deals with the penalty for causing water to be polluted by products of manufacture;

Section 131 deals with special water-supply districts, and the procedure for the establishment or disestablishment thereof, and by this section a Parish Council may initiate action; and

Section 132 deals with the powers from other Acts which are incorporated in this Act, viz., those already referred to.

The Burgh Police (Scotland) Act, 1892, confines itself to the provision of supplies to burghs.

Section 261 enacts that a burgh may erect waterworks, contract for a water-supply, or purchase.

The Commissioners are charged to provide "a supply of pure and wholesome water."

Burghs of less than 5000 inhabitants, where it is necessary in obtaining a supply of water to acquire land *otherwise than by agreement*, may, instead of proceeding under the Public Health Acts, present a petition to the Sheriff and obtain his authority to put in force the provisions of the Lands Clauses Acts.

Section 264 enacts that water is not to be used by consumers, without special agreement with the Commissioners, for other than domestic and ordinary purposes; should, however, the supply be more than adequate for such use, the Commissioners may grant its use for other public and private purposes; and

Section 269, that the provisions of this Act are not to apply to any burgh which before the 31st December 1894, is supplied with water under powers of local Act or Acts.

III. *Law of Ireland.*—This is embodied in the Public Health (Ireland) Act, 1879, sections 61 to 79, with certain clauses from the Lands Clauses Acts, as amended by the provisions of the Working Classes Act, 1890, second schedule.

On main lines, Irish law relating to water-supplies differs in nothing essential from that of England with respect to powers, but in respect of procedure there are very important differences.

Under the section dealing with the "power to purchase lands" the Irish Act confers upon every sanitary authority the power to acquire compulsorily sources of water and water way-leaves, since the term "land" includes "any land covered with water, or any water, or right to take or convey water." Further, by provisional order compulsory powers may be granted for the purchase of water sources for water for "drinking and domestic purposes." And in cases with respect to the purchase and procuring of land *other than by agreement*, procedure is simplified by this Act, section 8, which enacts that the provisions of the Lands Clauses Acts shall be amended by the provisions of the Working Classes Act, 1890, second schedule. So that when plans for a proposed water-supply have been lodged with the Local Government Board, an arbiter is appointed by the Board, who hears and examines claims, and, thereafter, makes his award, which is final.

Hot-Water Supply of a House.

In most houses of any pretensions which are supplied with water from a gravitation supply, a hot-water system for the supply of hot water for culinary purposes, baths, wash-hand basins, etc., is commonly introduced. The source of heating the supply is a boiler which is placed behind the fire of the kitchen range, is commonly of a saddle or horse-shoe shape, and is constructed of iron or copper. In such an installation, a cistern must be placed at the top of the house, the position usually chosen being one between the ceiling of the topmost room and the roof of the house, so that from the contents of the cistern cold water may fill the place of the hot water drawn off at any point of the supply. By the house-branch pipe from the street water-main, water is conveyed to this cistern, which is the highest point of the circulation. The supply from the

cistern is solely intended for the hot-water system and to feed the boiler. The water from it may be used for cooking provided that all risks of contamination and pollution are prevented. This may be accomplished by constructing the cistern of slate, covering it with an iron, slate, or wooden hinged lid, and ventilating it by means of openings for the outlet and inlet of air, as shown in Fig. 157. In most houses, unfortunately too little attention is paid to this cistern, with the result that it very often becomes a receptacle of miscellaneous material, of which dirt from the roof, the decomposing bodies of drowned mice and rats, and plaster are common examples. Owing to such pollution risks to health are engendered. Unless, therefore, every care against contamination has

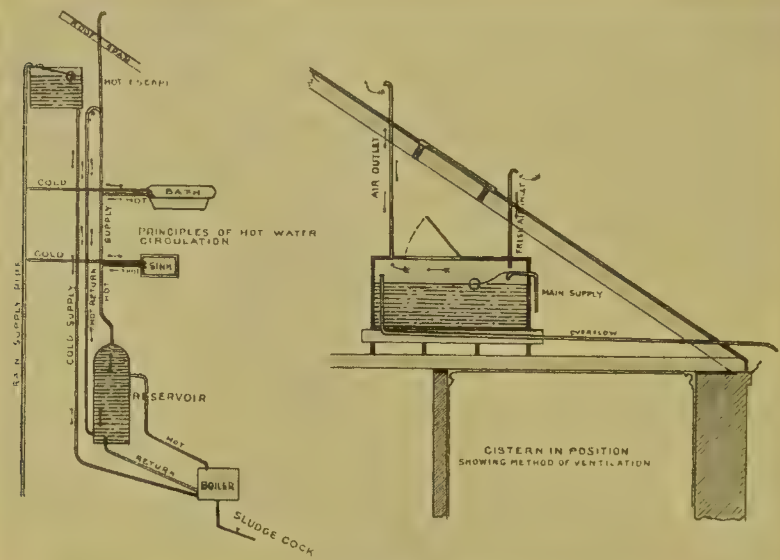


FIG. 157.—The Figure on the left of the Diagram illustrates the principles and mechanism of Hot-Water Supply to a House. The Main Supply Pipe conveys water to the cistern—the highest point of the circulation—and from this pipe branches are connected to Baths, Sinks, Wash-Hand Basins, etc. From the cistern proceeds the cold-water supply pipe to the hot-water boiler behind the kitchen-fire, which it enters close to its bottom. From the top of the boiler passes the hot-water pipe to the reservoir or hot-water storage cistern from which proceeds the hot-water supply pipe, by branches from which various fittings are supplied with hot water. The hot water not required passes back by means of the hot-water return-pipe, in a partially cooled state, to the lower level of the hot-water storage cistern to aid in the supply to the hot-water boiler. The course of the circulation of water is indicated by the arrows. The figure on the right shows a model method of ventilating and keeping clean the contents of the cold-water cistern. The top of the cistern is covered, and a hinged lid permits of sufficient space for inspection and repairs. It is ventilated by openings in pipes which open below in the cistern in the air-space above the water-level, and, above, into the open air above the roof.

been taken in the construction of the cistern, it is wiser that the water, unless for ordinary culinary operations, should not be used. By means of a system of pipes which forms a complete circulatory apparatus, hot water is conveyed to the different parts of the house where it is needed, and the pipes are kept constantly full from the cistern in the roof. Reference to Fig. 157 and to the explanation given will provide the reader with an intelligent conception of the principles of hot-water circulation.

The course of the circulation—assuming for the moment that the circulation is being established for the first time—is as follows: From the cold-water house-supply-pipe water rises to the roof-cistern, which it fills to a certain level. This level is regulated by a ball-valve which, rising with the water-level, gradually cuts off the water-supply as the fixed level is reached, and finally stops the supply when that level is attained. The cistern is provided with an

over-flow pipe, which is only operative, however, should, from any reason, the ball-valve fail to act. This over-flow pipe is passed through the roof to the outside of the building at a point usually a little above the level of the eaves. From the cistern passes the cold-water supply pipe to the boiler in the kitchen range, into which it enters near its bottom. From the boiler proceed two pipes—one from the top of the boiler carrying upwards the heated water to the hot-water reservoir, or hot-water cistern as it is commonly called, and another from the lower part of the boiler but at a higher level than the cold supply-pipe, which acts as a return pipe from the hot-water reservoir. This reservoir is usually placed in the kitchen near the roof at some convenient point, or in the bathroom where that apartment is located in the flat above and over the kitchen—as is not uncommon in small villa houses—in which case it warms the bathroom. From the top of the reservoir passes the main hot-water supply pipe, from which branch pipes pass to the necessary fittings in the house. This pipe is continued up through the different flats, and terminates in a curved ending outside the roof, thus acting as an expansion pipe. Since the water in this pipe will rise nearly to the height of its source, *i.e.*, to the bottom level of the roof-cistern, the sanitary fittings in the top flat may be supplied with hot water. In order to maintain the principle of a circulatory system, a pipe is connected with this hot-water pipe near that level, by which the water may pass back to the hot-water reservoir. This pipe in plumbing language is called the *hot-return-pipe.* In this way, therefore, the circulation of hot water is maintained so long as the roof-cistern contains water. But there are certain risks attaching to hot-water installations. These are dependent entirely on a failure of supply of cold water to the boiler. Should for any reason—as freezing of the contents of the house branch pipe or the cistern, or failure of supply owing to necessary repairs in the street mains—this happen, and should the hot water in the pipes be drawn as usual for the needs of the household, the pipes are gradually emptied, and there is a likelihood that steam will be generated in the reservoir or boiler owing to "short circuiting" of the circulation. In the system shown in Fig. 157 this is unlikely to happen, because long before risk of explosion has become imminent—if such a risk could happen at all—attention would be drawn to the unusual condition by the lack of hot water in the pipes of the upper rooms, and thus forewarned, time afforded so that the services of a skilled workman could be obtained. Disastrous explosions, accompanied even by loss of life, have, however, not infrequently occurred where certain forms of hot-water installation other than that shown in the figure have existed. Various measures have been proposed to prevent such occurrences. Owing to the great household discomfort which follows the withdrawal of the kitchen fire for even comparatively short periods of time, the following measures have been proposed to allow the kitchen fire being used, viz.: the temporary extinction of the fire and then to block the passage below the boiler against the flames with a poor heat-conductor, as fine ashes, or to put a false back to the fire in the form of a sheet of iron and to fill an interspace between it and the front of the boiler with the same non-conducting material. Some, however, have proposed, as a safe preventive under any circumstances, to put an escape or safety valve in the upper part of the boiler itself, which would permit the escape of steam at its first formation, relieve internal pressure in the boiler, and so prevent the possibility of the occurrence of an explosion.

CHAPTER VII.

HOUSE DRAINAGE.

THE waste matters which are formed in houses must be disposed of by suitable arrangements, and in populous centres, in addition, the refuse accumulations of the streets, and those arising from the keeping of animals. These waste products are comprehended under the following heads, viz.:—

(*a*) Liquid Refuse, including night-soil and waste-water;

(*b*) Ashes, food-waste, and other débris.

The former, in a water-carriage system, is called sewage, by which is meant everything which passes along the drains or sewers irrespective of its origin or character. It includes waste-water, excreta, rain-water, and trade discharges. The removal of solid débris of whatever kind, but chiefly that of households, is technically known as *scavenging*, while in towns where privies, dry-closets, etc., exist, the disposal of the contents of these and of the foregoing débris is spoken of as a *conservancy system*. In most large populous places, a water-carriage system of removal of sewage and a conservancy system are both required. In the economy of Nature, it was intended that the excreta of man should be returned to the soil to form the food of plants, but owing to the gregation of Man this intention has been disturbed. During the Middle Ages, and up till the first half of the last century, excrementitious products were accumulated in receptacles situated near occupied houses, and because of these epidemics broke out and death and depreciated health resulted. Even to-day the conditions respecting the removal and disposal of excreta and house-refuse vary. In villages and small towns where there is no public water-supply —a condition which is fortunately now rare—excreta are deposited in a privy connected with an ash-pit, and after accumulation are removed for agricultural use. In such circumstances, where houses are few and are distributed over a comparatively wide area, and where the domestic water-supply is not obtained from wells in the neighbourhood of such deposits, probably little or no harm ensues; and this is particularly true where earth-closets are in use, because of the deodorant and disinfectant properties of the earth used. In other small towns, or in individual houses, with a gravitation water-supply, and where there is no general concerted drainage system, although the sewage of the house is carried away by pipes, it is simply discharged into a cesspool sunk in the ground, over an adjacent plot of land, or into a neighbouring rivulet. But in modern towns and cities, such conditions have perforce disappeared. It may happen that in certain towns which have passed through different phases of sewage and refuse disposal, small areas are to be found in which the privy or ash-pit

system still prevails; but these are becoming fewer. In populous places, therefore, a well-conceived plan of sewage-convection and disposal must be in operation for the removal of human excreta, the liquid refuse of stables and cow-byres, refuse fluids from slaughter-houses and manufacturing processes, the waste-water of houses, and the rainfall.

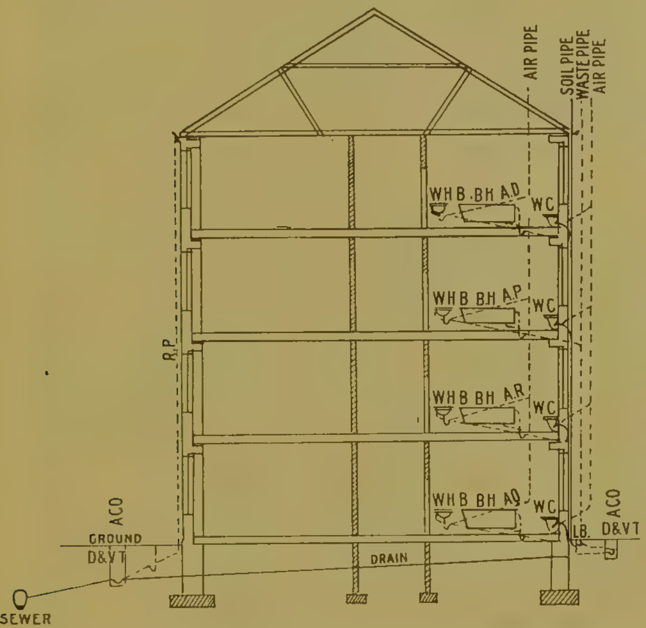


Fig. 158.—Arrangements of Draining a Tenement Property. WH.B. = Wash-Hand Basin; BH. = Bath; A.P. = Air-Pipe; W.C. = Water-Closet; D. & V.T. = Disconnecting and Ventilating Trap; Ac.O. = Access Opening; R.P. = Roof Pipe.

Leaving aside for the moment the disposal of solid refuse, attention may first of all be directed to the arrangements necessary in a dwelling which is connected with a water-carriage system of sewage.

The sanitary fittings necessary in a dwelling of the poorest class are the following, viz.: (*a*) a kitchen sink and waste-water pipes; (*b*) a water-closet. In better-class houses, in addition to these are (*c*) wash-hand basins, (*d*) baths, and (*e*) urinals. These fittings may be differentiated in respect to whether they contain or not excrementitious products. The bath, wash-hand basins, kitchen sinks, and rain-pipes belong to the waste-water system, the water-closet and urinal to the other. All the fittings of the former system are connected with the waste-water pipe, those of the latter with the soil-pipe. The rain-water pipes or conductors may, however, be separate. The contents of waste-pipe, soil-pipe, and rain conductors alike are ultimately discharged into the house-drain by which they are passed on to the sewer. Since the contents of the house-drain, and more particularly those of the sewer are in a state of active decomposition, and since foul-smelling and other gases are given off

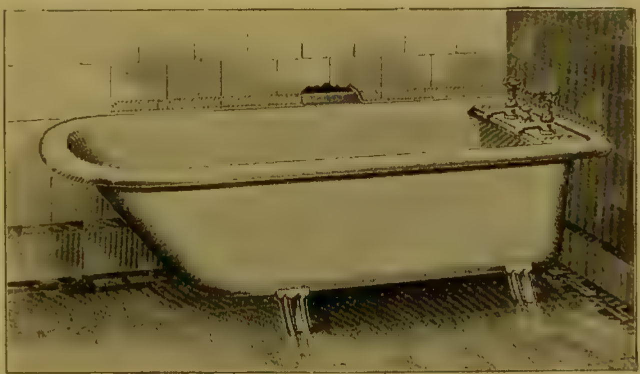


Fig. 159 shows a Modern Bath placed in position in a Bath-room in accordance with modern requirements, viz.:—Standing clear of walls and floor, and without surrounding wood-work.

therefrom, it becomes necessary to interrupt the continuity of the channels by the intervention of traps. The object of sanitary fittings, therefore, is not only to ensure the expeditious removal of liquid and solid excreta and waste-water from the house, but also the prevention of the possible return of gases of decomposition, etc., to the air of the dwelling.

The various above-named fittings must now be considered with reference to their fitness for the duty they have to perform. These

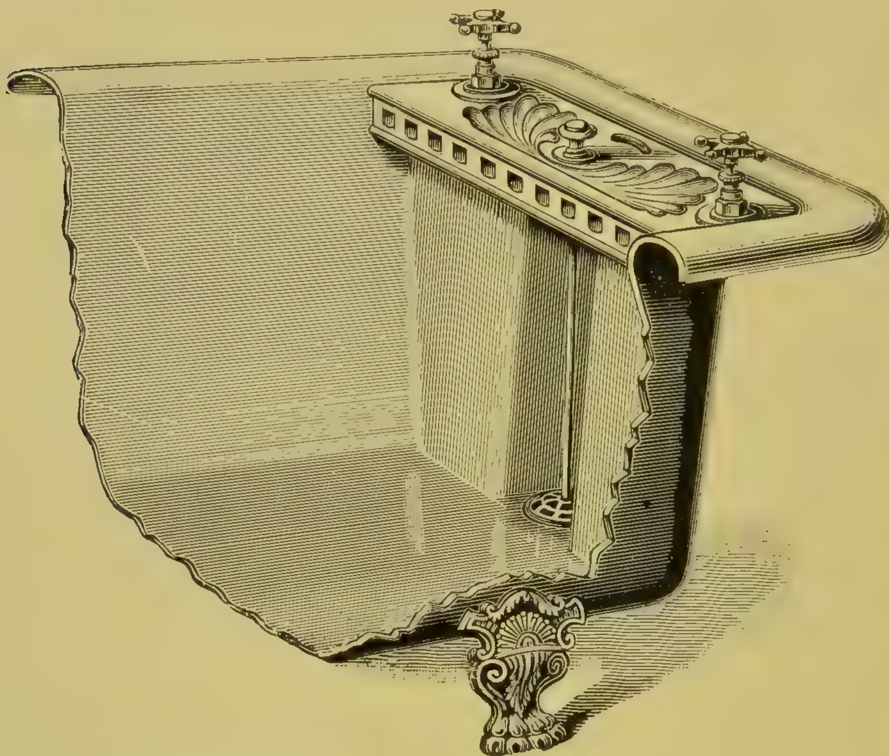


FIG. 160.—Bath fitted with single exit channel for waste-water and overflow.

will be dealt with under the heads of (A) Waste-water System, and (B) Soil-pipe System.

Waste-Water System.

(A) Belonging to the former are (1) Baths, (2) Wash-hand basins, (3) Kitchen and Pantry sinks.

Baths.—In the bulk of houses, the bath is placed in the same apartment as the water-closet and wash-hand basin, owing to exigency of space. There is no reason of a sanitary kind which can be urged against the practice, although there are of inexpediency. In many older houses in towns, particularly those in flats, the bath-room is too frequently an imperfectly lighted, ill-ventilated, and small room; in more modern dwellings, as it ought to be, it is well lighted and is capable of being well ventilated. The bath itself should stand clear of the floor, so that the space below and around it may be easily cleaned, and its sides should be placed away from a wall for the same

reason; and it should possess an ample supply of hot and cold water, the former preferably from the general house supply. It is usually constructed of cast iron. From it the waste-water and overflow are carried away by a branch-pipe to the waste-pipe, on which branch-pipe a trap is placed. For houses which possess no general hot-water supply, instantaneous heaters have been devised for baths, whereby, by a series of Bunsen burners which heat a convoluted pipe through which cold water passes, the water is heated.

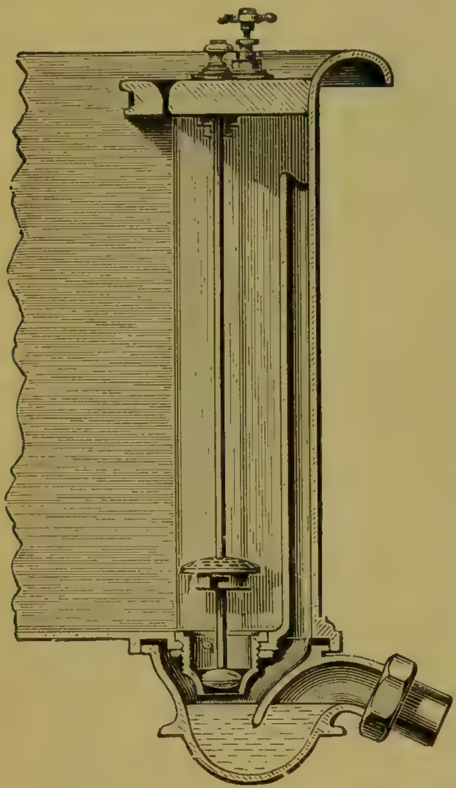


FIG. 161.—Section of Bath, showing arrangements for waste-water and overflow, with trap. When the water in filling the bath rises higher than the lower margin of the dark shading to the right of the Figure, it flows over directly into the trap by the channel seen on section at right margin of Figure.

Care must be exercised in the use of these owing to the generation of carbon monoxide gas, which has already caused fatal accidents. In most modern baths, the waste and overflow channels are combined by different makers, as is seen in the following figure. (Fig. 162.)

Wash-hand Basins.—These fittings are but miniature baths adapted in shape and in position for the purpose intended. The fittings of a basin ought to be exposed, like those of the bath, for the purposes of cleanliness and the better detection of leaks. The "tip-up" basin, which being mounted on a swivel may be quickly emptied, is a useful contrivance, inasmuch as the sudden rush of outflowing water assists to keep the pipes clean. The "aseptic" basin of Shanks & Co., intended for hospital use, is an ingenious arrangement for hand-sterilisation.

Kitchen and Pantry Sinks.—These are best made of enamelled iron or earthenware, and ought to be sufficiently capacious and of oblong shape, and the grated or perforated waste-pipe grated opening ought not to have too large openings,

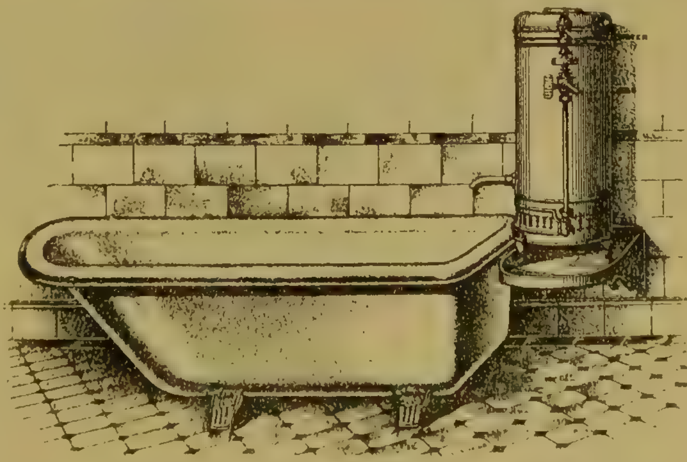


FIG. 162.—Bathroom fitted with Water-heater.

to prevent solid detritus being swept through and thus block the traps. Its fittings should stand open. It should not be surrounded

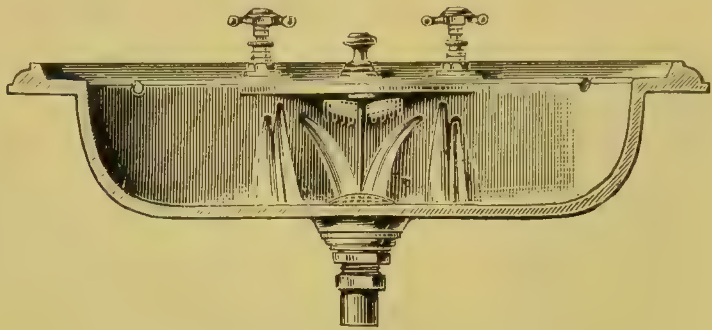


FIG. 163.—Elevation of "Aseptic" Wash-Basin.

by woodwork, because such hides an accumulation of dust and decomposing soapy and other materials. Since from such sinks greasy

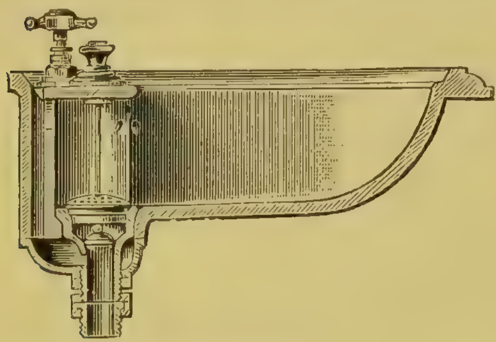


FIG. 164.—Section (longitudinal) of "Aseptic" Wash-Basin, with waste-water and overflow exit channel provided as in Baths.

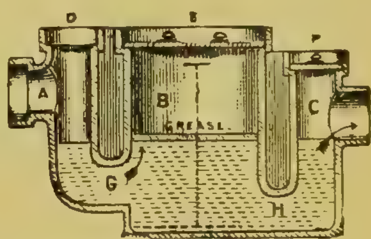


FIG. 165.—Buchan's Grease-Trap.

fluids are passed into the waste-pipe and drains, and since these are liable on cooling to coat the pipes and trap, and thus produce

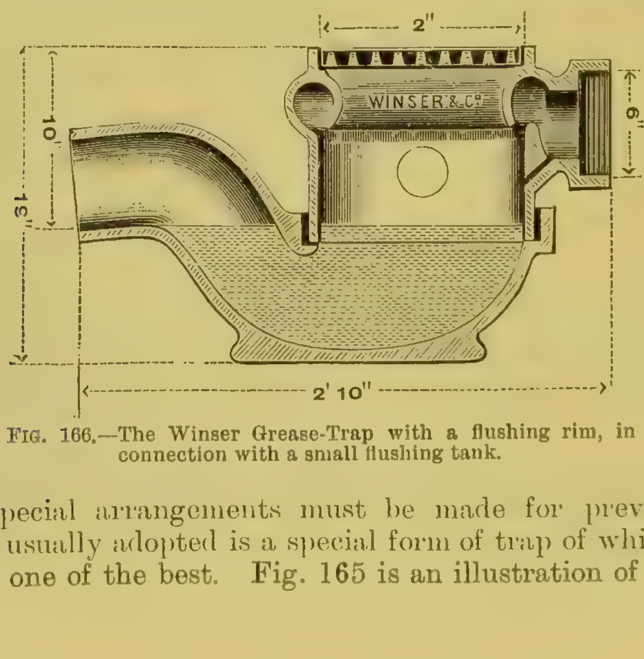


FIG. 166.—The Winser Grease-Trap with a flushing rim, in connection with a small flushing tank.

blocking, special arrangements must be made for preventing this. The device usually adopted is a special form of trap of which Buchan's is probably one of the best. Fig. 165 is an illustration of it.

The inlet is marked by A, and the arrows indicate the direction of flow of fluids; B is the grease chamber in which fatty matters solidify, and from which they may be removed periodically by the movable cover E; C is the outlet, by which grease-free water passes into the house-drain; D and P are openings by which the trap may further be cleansed. The congelation of the fatty matter is assisted by making the inlet of the trap higher than the outlet, and the tongue of the trap nearest the outlet lower than that nearest the inlet. The trap is placed in an accessible position for cleansing, and serves efficiently its object.

The contents of these fittings are discharged into the *Main Waste-Water Pipe*. This pipe may be made to pass downwards from the highest fitting either on the inside of the house wall or on the outside. Provided that at its lowest part it passes to the exterior of the house, and that it is disconnected from the house-drain either by opening

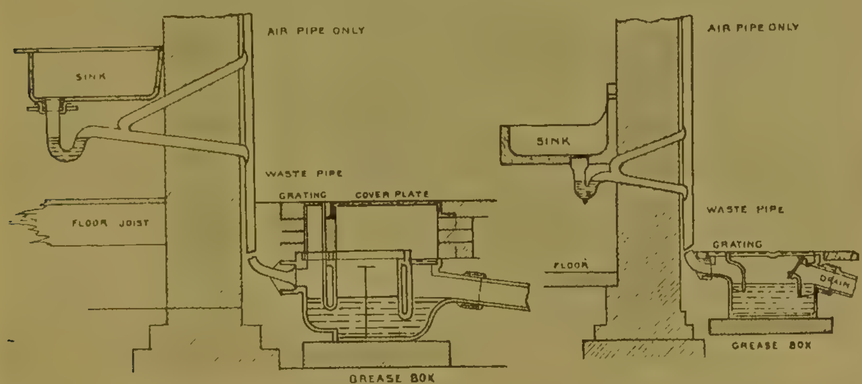


FIG. 167 is intended to illustrate the connections between the kitchen sink, waste-pipe, and grease-trap. It is to be noted that the grease-traps are placed in the Figures higher than they should be with relation to the flooring, solely for convenience of diagram-space. This is indicated by the severance in continuity of the waste-pipe before it enters the grease-box or trap.

over a trapped gully or into a ventilating trap, no strong objection can be offered to its being placed on the inside. Indeed, there are advantages associated with this latter location: its joints are less subjected to alternate expansion and contraction from heat and cold, and are, therefore, less liable to be loosened, the pipe itself is less liable to become warped, and its contents less likely to be frozen in winter. It is an open question whether a waste-pipe should be made to discharge its contents in the open over a grated gully at the ground level, or should be made to do so into a ventilating trap below that level. The determining factor ought to be the exposure of the pipe in respect of the points of the compass. If the exposure is on the south or west, the open method is probably the better; if on the north and east, the underground method. The reason for this is the liability of the mouth of the grated gully to become frozen over, if blocked by partial obstruction, and succeeding discharges of waste-

water from the house-fittings to be diverted over the surface of court-yard or pavement instead of passing into the house-drain.

Rain-Water Conductors.—These pipes belong to the waste-water system. In many cases they are formed by an extension upwards to the eaves of the waste-pipe, where they are connected to the eaves-channels. But in large buildings, they are also found as separate pipes. If they are joined to the house-drain, as they usually are, they must be trapped, especially where at the eaves they are in close proximity to attic or other windows. Their contents are commonly discharged into court-yard gullies, which are made of special form to

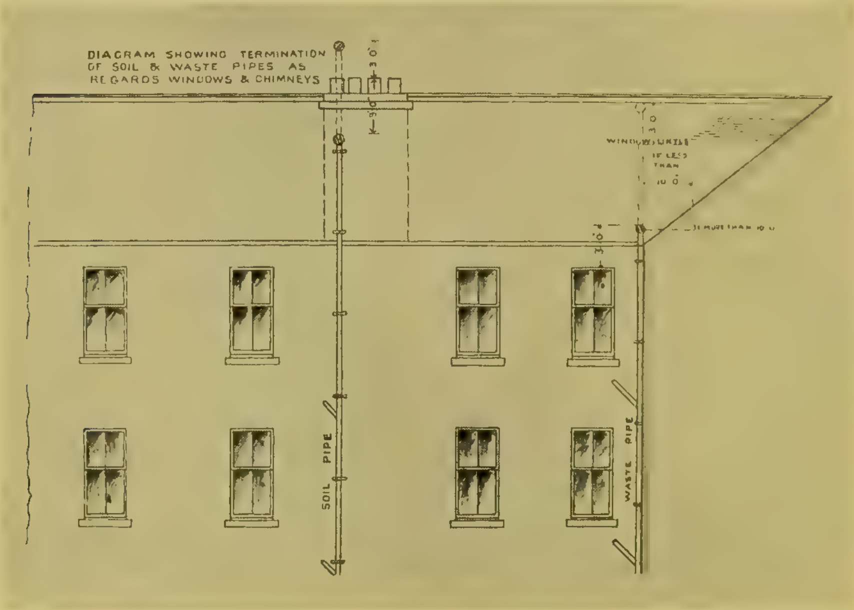


FIG. 168.—To illustrate the relations of ventilation of soil-pipe and waste-pipe to windows and chimneys of dwellings. In Building Regulations of various towns and cities, the upper end of soil-pipes must not be less than 8 feet clear of windows. No soil-pipe terminus should be within 3 feet over or under a chimney-top. Waste-pipe termini should not be less than 5 feet from a window or chimney, or less than 3 feet if the window or chimney be within a radius of 10 feet.

arrest any solid matter which may be carried into them by the rainfall. This solid residue is periodically removed.

From the foregoing, therefore, the following principles may be enunciated: firstly, that all fittings which discharge waste-water should be connected with a waste-pipe only; secondly, there ought to be no communication between waste-water fittings and the soil-pipe system.

It has been urged, however, by some sanitary engineers that there is no need whatever for two parallel pipes from a bath-room, one for carrying away waste fluids and the other night-soil, provided that the plumbing workmanship is thorough, and that it has been subjected to a sufficient test to establish its efficiency. Such argue that both pipes are more or less foul, they both carry fluids of different degrees of pollution, and both have the same destiny; why, therefore, since each fitting which is connected with the separate waste- and soil-pipes at present is separately trapped by a ventilated trap, need there be more than one main pipe which should combine the duties of waste- and soil-pipe.

Much can be said in favour of this view; first, it reduces the number of channels connecting the house-fittings with the house-drain; second, the soil-products would be better flushed into the house-drain; and, generally, removal of all products would be simplified. These are legitimate arguments when the integrity of these channels can be assured by periodic testing, as ought to be done, but so long as such channels, their branch connections, and their traps are liable to imperfect construction, and are not tested at periodic intervals, the connection of waste-water fittings to a soil-pipe would multiply the chances of sewer-air and foul gases gaining an entrance into houses. Until, therefore, such periodic testing of sanitary fittings becomes a more prevalent practice, it is safer to have separate channels or pipes to carry away waste-water and excretal products respectively, and to disconnect the former pipe from the house-drain before its entrance thereto.

Soil-Pipe System.

(B) *Soil-Pipe System.*—The fittings in the dwelling which belong to this system are the following: (1) Water-Closet and Slop-Closet; (2) Urinal; (3) Main Soil-Pipe.

Water-Closet.—The apartment in which this fitting is placed ought to be capable of free ventilation. For tenements, where the apartment is used by many persons, the system of "cross" ventilation, which may be secured by providing windows in the walls of the apartment at right angles to the doorway, is the best. Every apartment of this kind should, compatible with personal comfort, be abundantly flushed with air. In most "flatted" houses of four or more rooms of the older type, this apartment is supposed to be ventilated by a window which opens upon the landing of the common stairway. As a matter of fact, however, by reason of the higher temperature of the house interior, the direction of the current of air is from the window in question through the closet apartment into the dwelling itself. In more modern dwellings, the position of this apartment has been improved, but the mode of ventilation, in the above sense, is not different.

In the Model Bye-laws issued by the Scottish Association for the National Registration of Plumbers, it is suggested that no water-closet should be placed in an apartment which has not an external wall for one of its sides, and which does not contain a window in such wall of at least 6 superficial feet of glass, and which has not one half of the window made to open; such apartments in top-flats, however, may be lighted and ventilated from the roof. The object of this is to provide better facilities for placing the soil-pipe on the wall outside of the dwelling. In Section 251 of the Burgh Police (Scot.) Act, 1892, the above provisions are enacted. In Section 53 of the Glasgow Buildings Regulations Act, 1900, the minimum window space is fixed at 6 superficial feet, the window being constructed to open to the extent of at least one half. The Regulations of Aberdeen and Greenock contain like provisions to the above model bye-law in respect of the position of the water-closet apartment, but the lighting and ventilation must be sufficient, although the particulars of the window-dimensions are not specified.

During the last twenty-five years the water-closet has undergone a variety of changes, and that toward perfection. Although its use was not unknown in the days of Pompeii and, in isolated instances, in this country in the sixteenth century,—as, for example, "A Priuie in Perfection," the plans and working parts of which are described by Sir John Harington in a work entitled, "A New Discourse of a Stale

subject called the Metamorphosis of Ajax," 1596,[1]—the first water-closet was patented—a valve closet—in 1775 by Alexander Cummings. Bramah, the famous mechanician, also invented a valve closet which is still called by his name. Since then, many patterns have been invented and many patents taken.

The closets in use at the present time belong to one of four different classes, viz. :—

(*a*) The valve closet;
(*b*) The pan closet;
(*c*) The hopper closet;
(*d*) The "flush" closet.

The Valve Closet.—The chief merit of this form is that the contents are suddenly projected into the trap on release of the valve, and the chief objection, that the valve is liable to be unfitted from the valve-seat by any substance which becomes lodged at the valve-seat, thereby allowing leakage of the water which should remain in the fitting. Except in the case of one or two specially good forms, the valve-closet has largely gone out of use. (Fig. 169.)

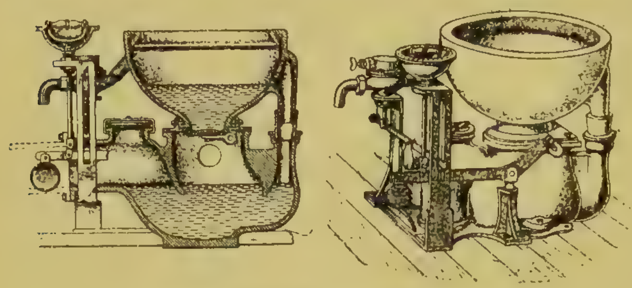
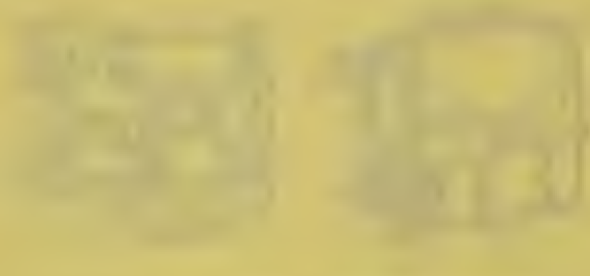


FIG. 169.—Valve-Closet, Section and Elevation.

The Pan Closet.—This form is still largely used, but is not now being put into new houses, the more modern forms taking its place. Its installation into new buildings or old buildings remodelled is prohibited by the Model Bye-laws of the English Local Government Board. Bye-law 65 of the Glasgow Buildings Regulations Act forbids that any container or other similar fitting should be placed beneath the closet-basin; each closet must be provided with a suitable trap, but no D-trap or lead mid-feathers shall be regarded as suitable. It is composed of the following parts, viz.: (1) an earthenware basin; (2) a copper pan which forms the bottom of the basin, and by which a certain amount of water is retained in the basin; (3) the receiver, trunk, or container composed of rough cast iron, into which (1) and (2) are fitted; and (4) the trap. The handle of the closet which is pulled upwards, operates at the same time to open the cistern for flush water and to depress the pan, thus emptying and flushing the pan at one pull. The obvious objections to it are, first, that it is composed of too many parts; second, that the very parts which require cleansing are most difficult of access, and third, that the trunk or receiver becomes coated with excreta, and because of its greater width and area than the pan, cannot be flushed with water. Whether the trap attached to it be a D-trap or an S-trap, it is a most objectionable form of fitting, and it ought to be removed from houses.

The Hopper Closet.—These, especially the long conical hopper, have fallen into desuetude; the long hopper particularly, since it is

[1] *B. M. J.*, vol. ii. 1900, p. 1861, *et seq.*



impossible to clean it with any flush of water. Less objection can be offered to the short hopper, provided the water-flush be sufficient.

Flush Closets.—These are best when composed of one piece of earthenware, since trap and closet being combined there are no joints liable to become loosened. Such apparatus, when fitted with a movable hinged seat, may serve the purposes of a urinal and slop-

FIG. 170.—Tylor's Wash-down Closet. The basin is purposely widened to enable the apparatus to be used also as a slop-closet.

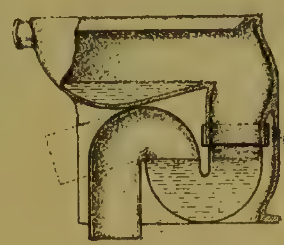


FIG. 171.—Section of a Wash-out Closet.

closet. They have no mechanism to get out of order, they can be fitted in position without any surrounding wood-work, and they can be easily cleaned.

They are divisible into two main forms, depending upon the mode of action of the water-flush upon their contents, and they are called

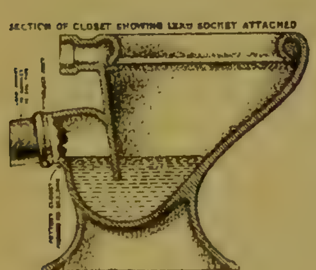


FIG. 172.—Section of a Wash-down Closet.

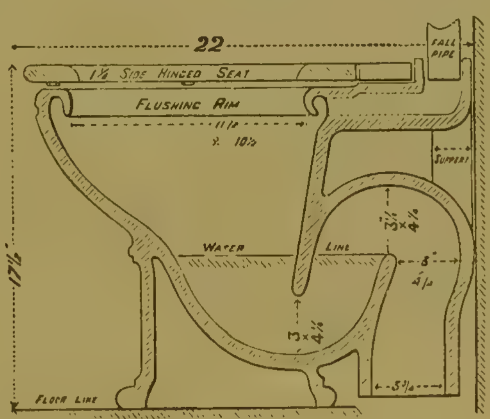


FIG. 173.—Section of Wash-down Closet showing the Closet fitted in position.

Wash-out and *Wash-down* closets respectively. In the wash-out closet the excreta are deposited upon a projecting ledge within the basin, and because of the action of the water-flush in washing out such deposit into and through the trap, it receives the above name. In the other class the action of the flush is to *wash down* the excreta through the trap, since primarily, in this form, the excreta are deposited straight into the water of the trap. It is therefore apparent that

with an insufficient water-flush there is more likelihood of imperfect action in the wash-out than in the wash-down closet, and since part of the force of the flush is spent in overcoming the extra resistance of the ledge, and in sweeping the contents into the trap, the excreta may be left in the water of the trap, instead of having been swept through it and into the soil-pipe. Where however the water-flush is sufficient, there is little to choose between them in respect of efficiency. Of this same type of closet, but with special arrangements for emptying, is the "Siphonic" Closet, which is so called because the contents of the basin are emptied by siphonic action. In its most modern form it is a good closet. The action of the siphon is started by the direct action of the water from the flush-pipe. In the "Levern" closet, the lower part of the long leg of the siphon is of patented construction and is made of lead.

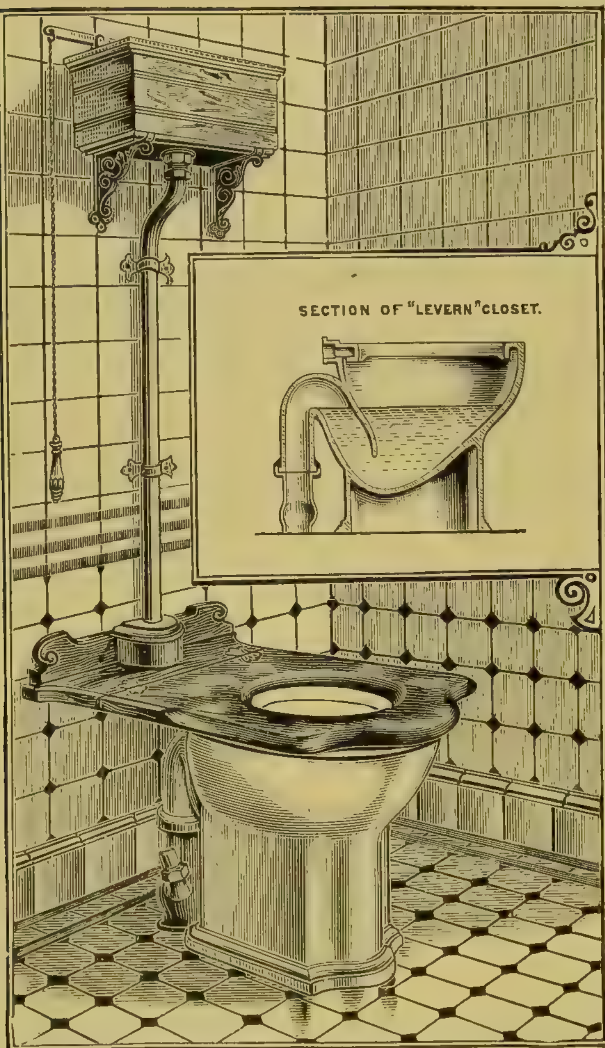


FIG. 174.—Elevation of the "Levern" Siphonic Closet, and section of basin and connection with branch-pipe.

A necessary part of such a closet is an efficient cistern, which is commonly sold by the makers as part of the fitting in order to ensure effective action. The objection to these closets which operate by siphon action, is that the siphon action may be initiated by throwing in slop or other waste water, and thus the trap may be left unsealed. This, however, has been overcome in one of two ways, viz.: (*a*) either by introducing an anti-siphonage pipe which prevents the action of the siphon except by the flush set agoing in the ordinary way; or (*b*) by fitting it with Dicksee's patent arrangement, whereby, if the siphon action is set up by the addition of extraneous water, cistern action is simultaneously set up, and thus the trap is kept full of water. While, therefore, between wash-out and wash-down closets with good flush there may be little to choose, preference on the whole ought to be given to the wash-down form, since more effective flushing

of trap and contents results. But such apparatus must be periodically cleansed, else the inside of the trap, so far as it can be seen, becomes coated with deposit; and the best material for the purpose is a strong solution of washing-soda applied by means of a closet-brush.

The characteristics which a good closet ought to possess are the following, viz.: (1) It should be of such a form as to enable easy and perfect dislodgment of contents by the water-flush; (2) it should possess a sufficient trap; (3) all its parts should be accessible for cleansing; (4) the water-flush should be ample.

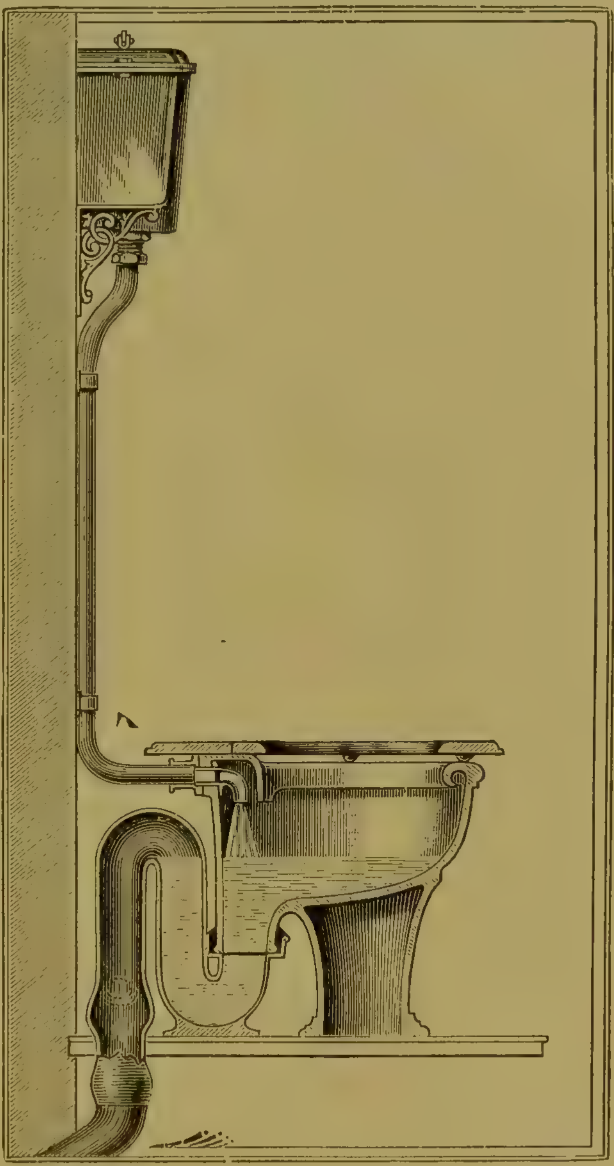


Fig. 175.—Section of "Levern" Siphonic Closet, showing siphon arrangements.

For schools and public conveniences trough closets are used. In these the basins open into a continuous water-receptacle which extends the whole length of the number of closets. They are either periodically flushed by an attendant, or by an automatically-acting flush cistern, when the contents of the water-receptacle are swept through the trap at the outlet end into the drain.

In certain towns, as Birmingham, closets are fitted for rows of houses upon the same principle, and the flush is obtained by the waste-water of the houses, which is passed into a tank at the end of the row furthest from the sewer. On the automatic action of the cistern when full the contents are swept into the sewer.

The Water-Flush.—The amount of water to be used as flush at each time of using a closet ought not to be less than two gallons, and when possible, should amount to three gallons. It should reach the basin of the closet by a pipe of not less than $1\frac{1}{2}$ inches in diameter. The cistern which supplies the flush should hold the quantity needed,

should be set in action by the user of the closet, should be beyond his control from the time of initiation till the completion of the act of

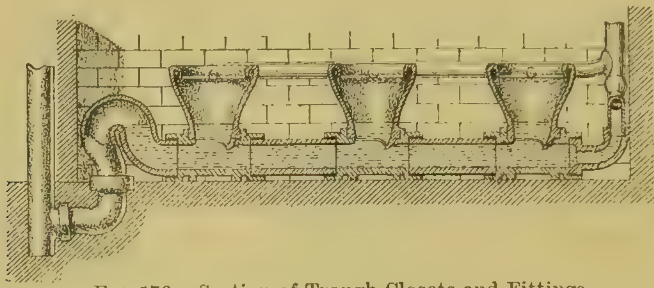


FIG. 176.—Section of Trough Closets and Fittings.

flushing, and should supply no other fitting than the closet. Any other arrangements than these are objectionable. If, for example, the flush supply is obtained from the cistern for the house hot-water supply, and if there be no arrangement for the regulated use of the needed quantity, either too much or too little water is used. To overcome this proverbial carelessness, arrangements in the mechanism of the closet have been made whereby the flushing is set in operation by closet-seat action. Fig. 177 illustrates this.

FIG. 177.—Elevation of Closet, in which flush is automatically started by the user.

But of all the arrangements in existence probably the best is that which secures, that when the operation of flushing is started it goes on to a finish without the attention or control of the initiator. In public conveniences, the siphon cistern which acts periodically and automatically is used. The cistern is usually situated against the wall several feet above the closet to give the water-flush sufficient velocity, but the action of such a cistern is usually accompanied by much noise. To overcome this, and where the arrangement of the apartment will not permit the introduction of a high-placed cistern, a combination of closet and cistern has been made. Fig. 180 is an illustration of the elevation plan of the fitting. It is claimed for this cistern that it is noiseless in action, discharges the full flush suddenly, and that the mere movement of a lever, seen on the left side of the cistern, secures the discharge of the whole contents of the cistern into the closet basin.

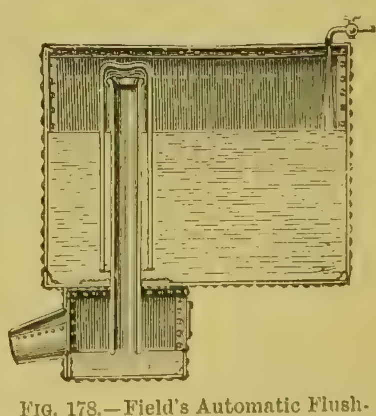
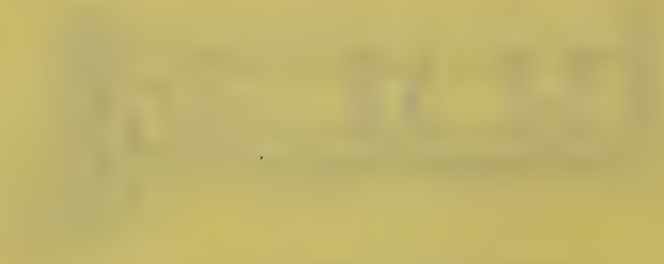
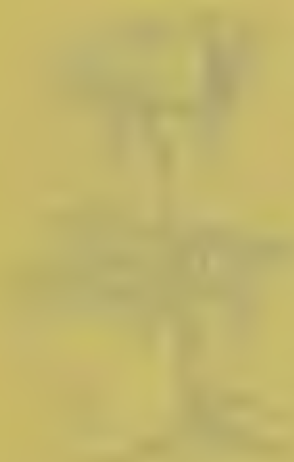


FIG. 178.—Field's Automatic Flush-Tank.

It has already been observed that a water-closet provided with a hinged seat may be utilised as a slop-closet; but it has one drawback





where many slop-vessels have to be emptied, and that is, there is no provision for washing clean the utensils after emptying. The

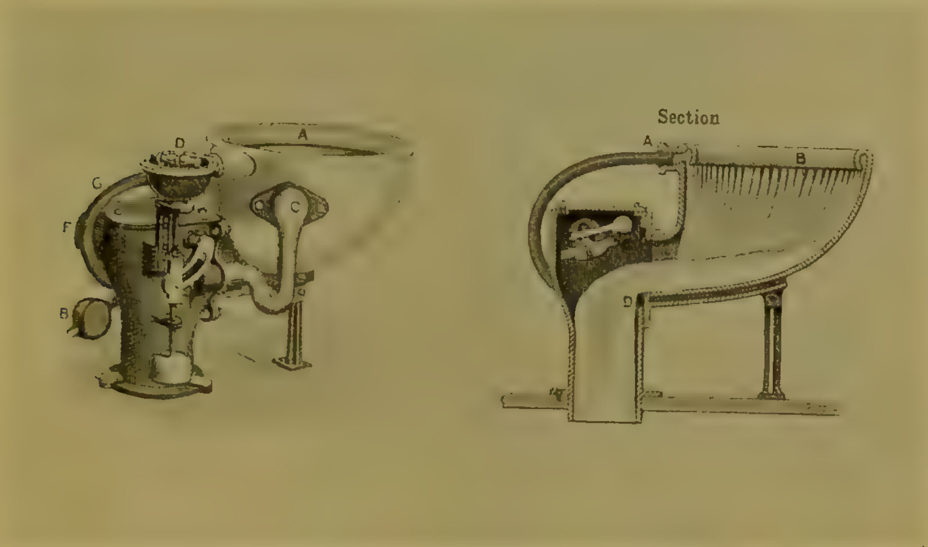


FIG. 179.—Trapless Water-Closet. This is a fitting which ought not now to be used.

FIG. 180.—Shanks & Co.'s Combination Closet.

arrangement shown in Fig. 181 is a fitting by Doulton for this purpose. Such apparatus is of great service in a large private house, in hotels, and in hospitals. Another contrivance for use in isolation

hospitals which can be fitted to the slop-closet, is a grid with perforated openings, which, when turned down over the slop-closet basin and the utensil placed over it mouth-downwards, throws upward streams of water into the vessel, and thus thoroughly cleanses it without the application of the hand, or other instrument.

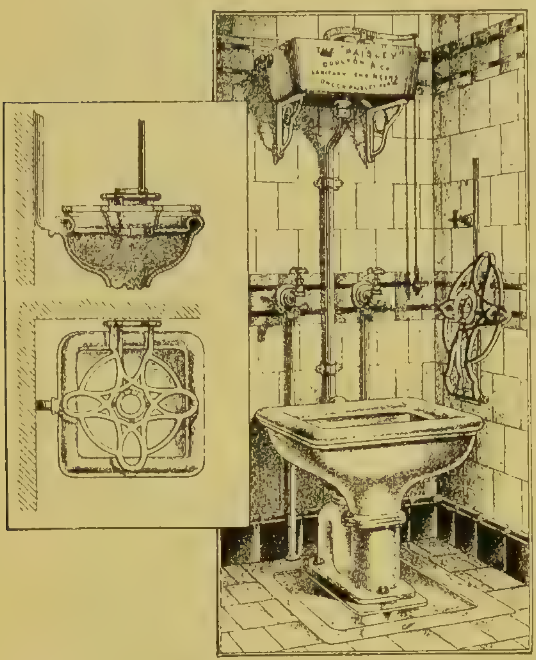


FIG. 181.—Slop-Closet fitted with grid for washing slop-utensils. It saves the use of the hands.

The Closet-Cistern ought to combine the following requirements, viz.: (1) To supply at each time of action three gallons of water; (2) to fill rapidly after being emptied; (3) to project the water suddenly and forcibly into the closet; and (4) to supply the same quantity of water at each action, irrespective of the user of the apparatus.

The water-closet pipe is joined to the soil-pipe by means of a branch-pipe which is composed usually of lead. The closet itself being earthenware and the branch-pipe lead, attention must be given to the mode of joining the two together, since by imperfect junction sewer air and sewer gases would obtain entrance into the apartment. Too commonly, the materials used are red lead cement and cloth. Owing to the different ratios of expansion by heat of lead and earthenware, this very soon becomes insufficient. This difficulty has however been overcome by the new metallo-keramic joint, which is composed of a combination of white metals, and forms not only at first a perfect connection but also, from observations we have made, a durable connection.

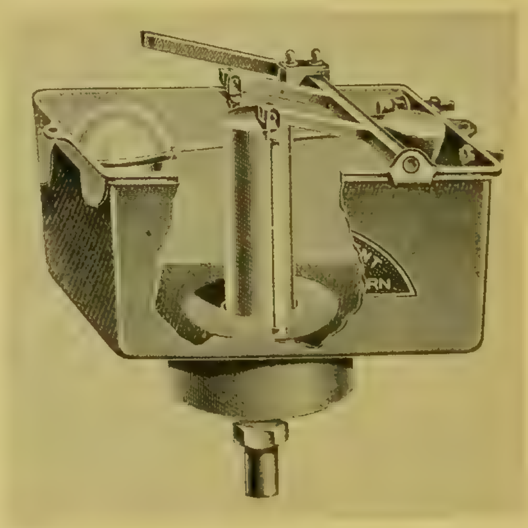


FIG. 182 represents an excellent type of Cistern—the "Reliable" Waste-Preventer.

The Soil-Pipe.—The pipe which is solely employed for the convection of excreta from a house is called the *soil-pipe*. It is composed of lead or iron, most usually of the latter. When of the former, its joints are rounded or flanged; when of the latter, of joints

"filled" with lead. No soil-pipe should be less than $3\frac{1}{2}$ inches internal diameter. If of lead, it should weigh not less than 7 lbs. per square foot, if of iron, 54 lbs. per 6-foot length. The joints between the lead pipe and vitrified material, in the case of lead, should be made by means of a brass ferrule which has an end flange of like diameter to the faucet of drain-pipe. The lead pipe passes through the ferrule and is soldered thereto by means of a wiped or burnt joint. This produces a better and more rigid joint than any other method. In the case of iron, the joints are made with rope yarn and molten lead.

Since the soil-pipe is employed for the above purpose it should be placed on the outside of the house-wall. Each closet, slop-closet, and urinal fitting in the house is connected to it by means of a branch

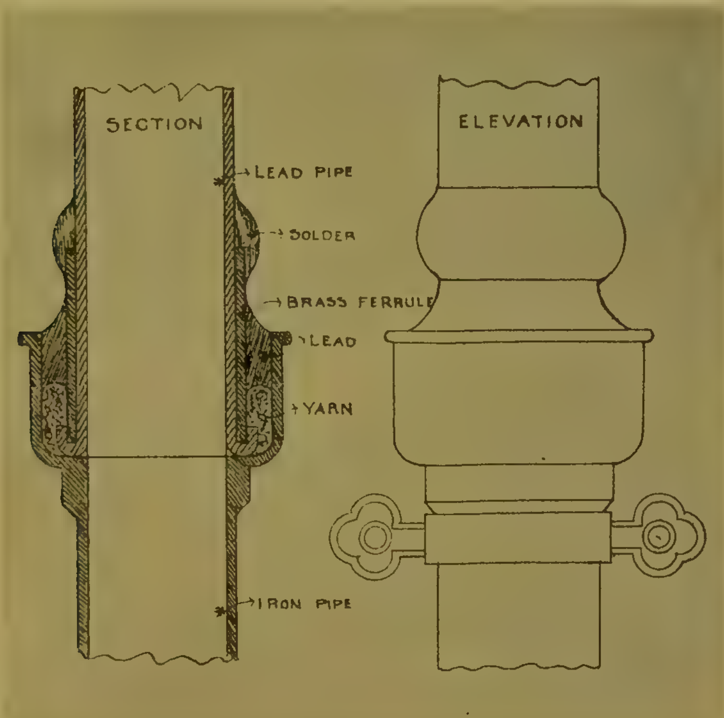


FIG. 183.—To illustrate mode of uniting a lead with an iron pipe by means of a brass ferrule.

connection which is trapped between the point of connection and the fitting, usually near the fitting itself. Fig. 168 represents the position of the soil-pipe on the house-wall. The soil-pipe should extend from a point three to five feet above the eaves to below the level of the ground where it is joined to the house-drain. Its diameter should be the same throughout its whole length, and curves and angles should be avoided lest accretions of filth form in its interior at such points, and also in order that ventilation through it is not reduced.

The diameter of the pipe must depend upon the work it has to do, and therefore must be relative in size to the number of fittings which empty into it. For an ordinary house of two or three flats a 4-inch pipe will be ample; but for larger buildings, such as hotels, barracks,

etc., a 6-inch pipe may be required. The topmost opening should not be near attic windows: if its course should run in such a direction the top of it ought to be carried for at least three feet above the window.

At some point between the junction of the soil-pipe with the house-drain and the sewer a disconnecting-trap is commonly placed, in order that by the ventilating opening of the trap air may enter and pass through the whole shaft. Objections have been offered, however, to placing a trap in this position, particularly at the point of junction of pipe and house-drain, since resistance is offered, it is urged, to the free egress of sewage from the house sewer-ward. But if ventilation of the soil-pipe is to be secured, it must be effected either in this way or by erecting a separate ventilating shaft to allow of the liberation of pressure of air which may take place in the sewer. If the ventilation

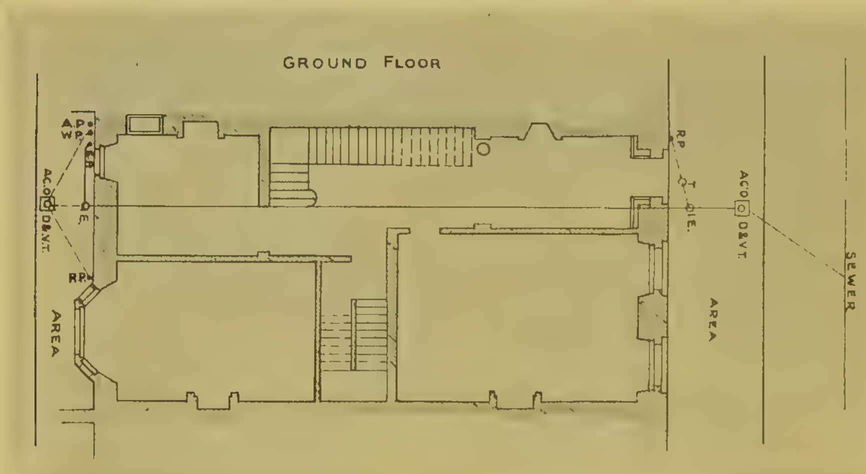


FIG. 184 illustrates a Model Ground Plan of Draining a House in a Terrace. A.P. = Air-Pipe; W.P. = Waste-Pipe; S.P. = Soil-Pipe; I.E. = Inspection Eye or opening; R.P. = Roof-Pipe for carrying Rain-Water; Ac.O. = Access Opening; D. & V.T. = Disconnecting and Ventilating Trap; T. = Trap. From the figure it will be seen that the soil-pipe and waste-pipe pass down on the outside wall of the back of the house to the Disconnecting and Ventilating Trap in the back area, that the combined waste-water, roof-water, and soil pass by the house-drain underneath the main passage in the basement of the house to another trap in the front area, and thence to the sewer in the street.

of the sewer itself be ample, however, it is contended that there is no likelihood of pressure forming therein sufficient to force the traps of the fittings which are joined to the soil-pipe. There is, at the same time, another objection to placing the disconnecting trap near windows, or on the pavement in streets, and that is because of the foul air which is driven out of the ventilating eye of the trap on descent of a column of discharging fluid. It is better to place the trap where it is least likely for the above reason to prove objectionable, and that position must be determined by individual circumstances. Periodic inspection of all the fittings of a house connected with the soil-pipe ought to be made, since for a variety of reasons joints are apt to become shaky, and to permit of the entrance of the soil-pipe air into that of the apartments. The lead which composes the branch connections and that of the filling of joints is liable to be attacked by the

gases dissolved in the fluids or by the fluids themselves which pass through them. This is specially true since disinfectants have come into popular use. The corrosion which is thus initiated tends to end in perforation. Another source of mischief is perforation of the pipes by rats in their eager quest for water. In Glasgow, several years ago, a mysterious outbreak of disease broke out in St. Mary's Reformatory, giving rise to anomalous symptoms, and which was believed by Dr. Russell, Medical Officer of Health, to have its origin in drain emanations due to this cause.

We have seen several examples of corrosion and perforation from the above causes. The piece of lead soil-pipe shown in Fig. 185 is in

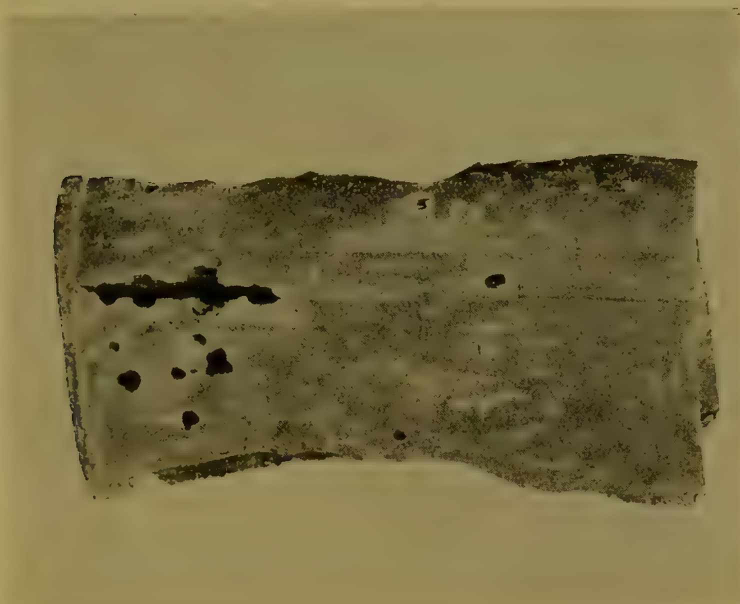


FIG. 185.—Portion of Lead Soil-Pipe eaten into and perforated by the action of sewer-gases. (In possession of Author.) In the house from which the above was taken, diphtheria and enteric fever had attacked the inmates more than once.

possession of the author. It was taken from a tenement building, from which enteric fever or diphtheria was hardly ever absent.

The House-Drain.—The house-drain is that part of the drainage arrangements of a dwelling which is situated between the point of entrance of soil-pipe and the common sewer in the roadway. Since the object to be attained is the carriage of the sewage and liquid waste products of the dwelling into the sewer by the effect of gravity, careful attention to its course and its levels is necessary. The course or alignment of a drain ought to be as straight as possible, and if curves upon it must be made, such must be open curves, in order to offer the minimum obstruction to the flow. It must be also placed on a gradient from the entrance of the soil-pipe—its highest point—to the centre of the street sewer—its lowest point. By proper alignment and gradient, therefore, expeditious removal of products is effected; where, on the other hand, bends exist in the course of the drain, resistance is offered to the flow, and the same effect is pro-

duced by insufficient gradient, hence "silt" is apt to form, and sooner or later, by the accumulation of silt or sediment, the drain acts imperfectly or becomes choked. Should the gradient be too great, the momentum of the passing discharges is apt to siphon the trap as the

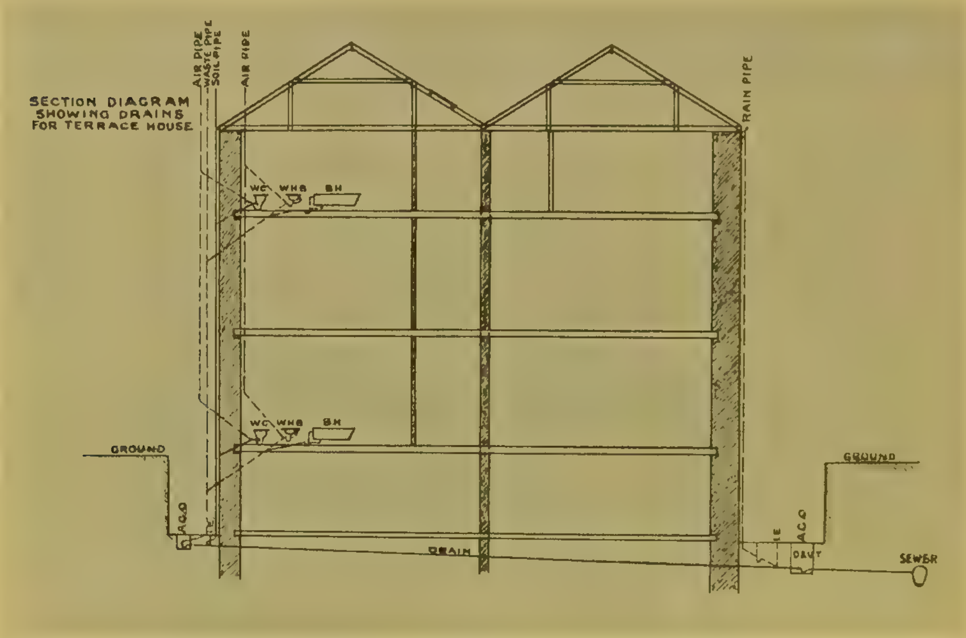


FIG. 186 is a Section Elevation Plan of a Terrace House, showing the arrangements of waste-pipe, soil-pipe, roof-pipe, traps, and house-drain. W.C. = Water-Closet; W.H.B = Wash-Hand Basin; B.H. = Bath. The other terms as in previous Figure (184).

discharges pass through. The fall or gradient therefore must have relation to the size of channel in order to obtain the requisite velocity of flow of liquid contents. The usual rule is: for a 4-inch pipe, a fall of 1 in 40; for a 6-inch pipe, 1 in 60; for a 9-inch pipe, 1 in 90. In the Model Bye-laws already referred to, the fall recommended for a 4-inch pipe is 1 in 36. This gradient has been adopted by Aberdeen. In Edinburgh, it is enacted that where practicable it shall be not less than 1 in 40, and in Greenock, not less than 1 in 48. In order to obtain these gradients, the level can only be properly adjusted by some such instrument as Moss-Flower's gradient indicator, as shown in the accompanying figure.

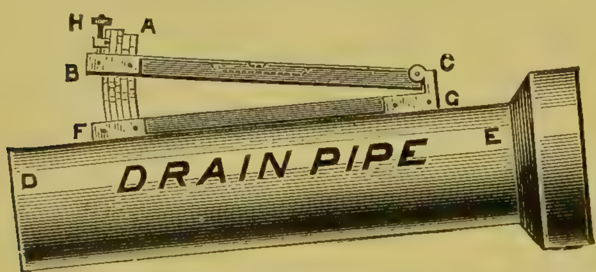


FIG. 187.—Gradient Indicator. A = brass scale to indicate gradient; B, C = spirit-level; D, E = drain-pipe to be laid; F, G = drain limb of instrument which is applied to line of pipe; H = tangent screw to secure exact adjustment.

The house-drain is commonly composed of fireclay pipes with spigot and faucet joints, but of late years it has been proposed to substitute iron pipes in their place. In the case where the house-drain,

by reason of architectural necessity or otherwise, is required to pass through or under a building, it should be composed of heavy cast-iron spigot and faucet pipes, the walls of which are not less than $\frac{3}{8}$-inch in thickness. The joints of a fireclay drain should be made with rope yarn steeped in cement rammed well home and Portland cement, each joint cleaned inside of "feathering," and left smooth; those of an iron-pipe drain should be made with rope yarn and molten lead. Where cement is used in jointing the section-lengths of fireclay piping, the work should be left for 48 hours to enable the cement to set thoroughly. Iron pipes used for this purpose ought to be coated externally and internally with Angus Smith's solution applied hot, in order to prevent corrosion, and if they are to be laid in earth their walls ought to be $\frac{1}{2}$-inch in thickness. In order to give stability and equality of resistance to pressure to the house-drain, it is necessary that it should be laid upon an even, solid foundation. If this be not done, some of the joints or pipe-lengths are liable to be broken on "settling" of foundations of house. The best foundation for a fireclay drain is a bed of fine concrete or cement, care being taken that the faucet ends of the pipes are embedded in the material. To ensure this, the lengths of fireclay pipes have been made with pedestal feet as shown in Fig. 188. The feet are embedded in the concrete or cement bed, and thus give fixity and stability to the entire drain. This is especially important where the drain passes through or under a building. In such cases, it is indeed better to envelop the pipe, except at the inspection openings, in asphalt, and a free overhead space of not less than 3 inches should be allowed at the walls or partitions for subsidence. And the same is true where buildings have been erected upon "made" or "filled" sites, owing to the greater liability of uneven settling of foundations. All junctions with a house-drain, whether horizontal or vertical, should be made obliquely and in the direction of the flow. Right-angled connections are quite impermissible, because of the obstruction to the flow thereby produced. Where drains from a large building converge, the junction should be effected obliquely by means of a bend (*vide* Fig. 191).

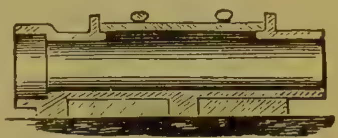


FIG. 188.—Fireclay Drain - Pipe Section made with pedestal addition, and with inspection opening on upper surface.

While it is a cardinal principle of house-sanitation that house-drains should not pass through or under buildings, it must be clear that this cannot always be achieved in towns and cities with continuous lines of streets of houses, and where the sewers are situated in the roadway. In order to avoid unsightliness of rows of pipes on the house elevations, the fittings of houses requiring waste- and soil-pipes are usually put in apartments at the rear of the houses. These, therefore, must enter the house-drains, which must be brought through or under the houses to enter the street-sewers. In tenement, flatted houses, the house-drain is caused to pass under the common entry, and in terraced, single-occupant houses through the passage in the basement flat of the house. If the constant integrity of the house-drain after efficient initial installation could be assured, it matters little whether

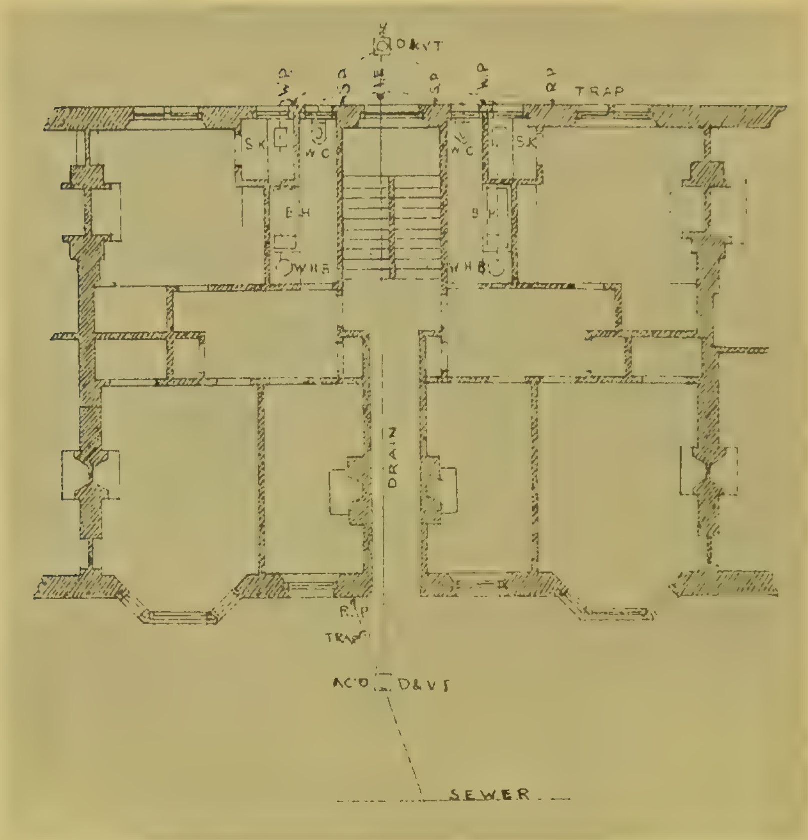


FIG. 189.—Plan of Draining a Tenement Property. The soil-pipes and waste-pipes pass down the back wall, and their contents into the house-drain, which, in order to reach the sewer in the street, is taken through the common entry. W.P. = Waste-Pipe; S.P. = Soil-Pipe; D. & V.T. = Disconnecting and Ventilating Trap; R.P. = Rain-Pipe; Ac.O. = Access Opening.

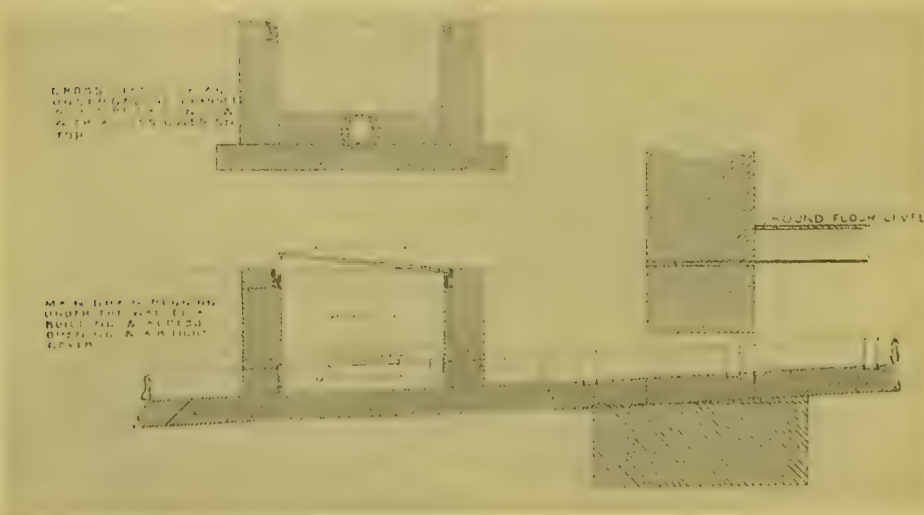


FIG. 190. To illustrate mode of laying a house-drain which runs under the wall of a building. The upper figure shows the cross section; the lower, the section elevation.

the drain be carried from rear to front through, under, or outside of the house; but in view of the absence of periodic inspection and the possible imperfection of the drain, special precautions must at first be taken to secure that it is air-tight. In such cases, the top of a drain should be not less than six inches below the level of the lowest floor beneath which it is put.

House-drains, apart from initial faults of alignment or gradient, may fail in their purpose from several causes, viz.: (*a*) rupture of pipes due to uneven settling of buildings; (*b*) want of connection with the street-sewer; (*c*) blocking of channel from accident or carelessness. By the Burgh Police Act, 1892, section 180, it is enacted that the entire drainage arrangements of a house must be inspected and tested to satisfy the Local Authority of their sufficiency. The Glasgow Building Regulation Act, 1900, section 57, prohibits the occupation of any new building, or of any old building altered for the purpose of increasing the number of occupiers, until these arrangements have been inspected and tested by the Sanitary Inspector and found satisfactory, and a certificate to that effect has been deposited with the Master of Works. In the case of new buildings, however, it does not appear to us that this test is sufficient of itself, since owing to the settling of the foundations during the early months of occupancy, some part of the drainage arrangements may have become broken, loosened, or even detached. Such would be indicated, probably, by cracks occurring in the walls of the house; in which case it would be absolutely necessary to re-test the integrity of the arrangements. But defects may take place in the drainage system without such marked signs as the foregoing, and, therefore, it would be better to renew the tests after some months of occupancy, the period to be determined by the character of the ground upon which the houses are built In view of such inspection, it would seem impossible that a house-drain from a tenement building could be left unconnected with the sewer. But we have seen such a case, where the defect was only discovered after the building had been occupied for a time sufficiently long to fill up the drain and internal fittings of the ground-flat houses with the accumulated sewage of the building. The liability to this is no doubt due in part to the dual control which exists in Scotland in the construction of the drainage arrangements of dwellings. While it is the function of the plumber to deal with the installation of water, gas, and sanitary fittings, with their necessary pipes and connections inside and outside of the house, the mason steps in and declares that the plumber's duty ends at the ground, and that it is the function of the mason to lay the house-drain and

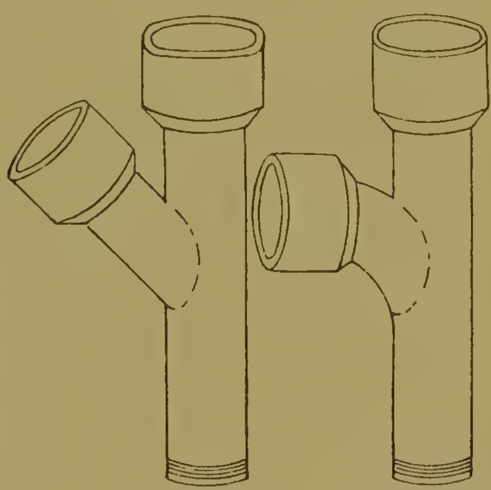


FIG. 191.—To show method of connecting Branch-Pipes with Main Drain-Pipe.

make the necessary connection with the sewer. So long as the house-drain continues to be constructed of fireclay with cement joints, so long will this controversy continue. It would cease at once, however, if it became the common practice to use iron pipes instead of fireclay pipes. There is much to be said in favour of placing the entire responsibility of workmanship upon one contractor, and of the use of iron instead of fireclay for house-drains.

Blocking of a house-drain not infrequently arises in tenement houses from carelessness or negligence of householders. Experience

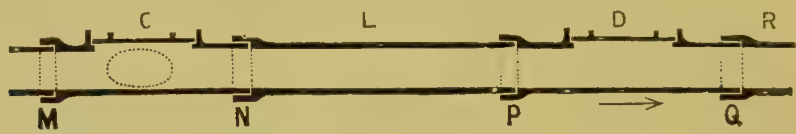


FIG. 192.—Section of House-Drain composed of Iron Pipes. D, C, movable inspection covers, by which interior of drain may be inspected or freed from obstructions ; C is placed at a junction. L is an ordinary pipe-length. M, N, P, Q indicate joints. The arrow points in the direction of the sewage-flow.

has shown that the obstructing causes may be scrubbing-brushes, washing-cloths, dusters, and sometimes materials much more foreign than these to house use. To overcome such obstructions, provision in

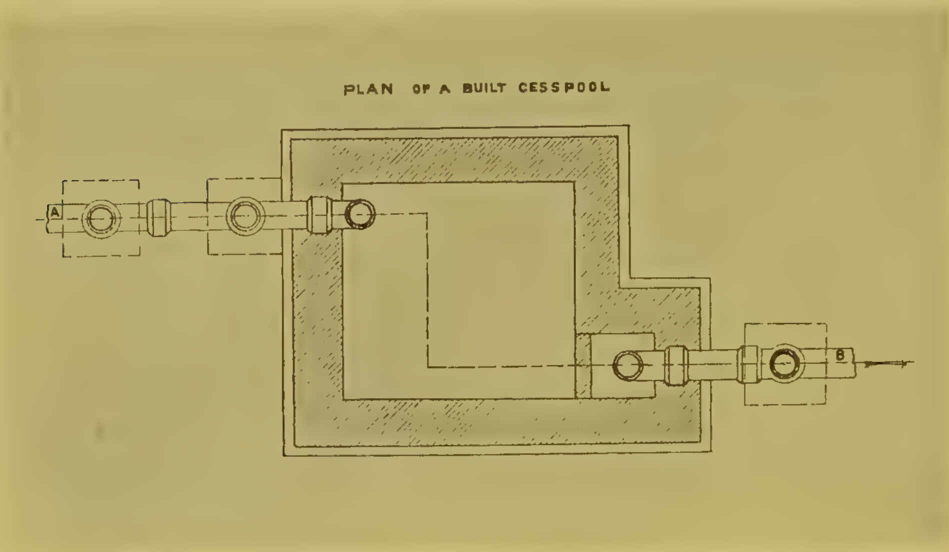


FIG. 193 is a Plan of a Built Cesspool or Inspection Chamber. The cesspool is constructed of concrete. By the fireclay pipe-channel A the sewage enters, and by the like channel B it leaves to be disposed of or purified. The top of cesspool is covered by a solid iron plate which can be removed for the purpose of cleaning the cesspool. (Model Regulations of Plumbers.)

the house-drain must be made in the form of access or inspection openings. These are provided with securely-fixed, air-tight covers, and are placed not only at junctions and changes of direction, but also at distances of from 20 to 40 feet apart in the straight course of a house-drain. Fig. 192 illustrates such in position. Such openings must be built to the ground surface of sufficient size to enable the introduction of flexible iron rods for the removal of obstructions.

Special care must be taken respecting the tightness of these openings in drains which pass through or under buildings.

For large buildings where a number of discharge-pipes converge at a particular point, it is better to construct an inspection-chamber, in the floor of which the main channel runs in an open form, and with which the branch connections unite. This chamber may be, indeed ought to be, situated as far from windows and doors as possible, should be ventilated by a shaft extending above the roof of the house or houses, or by one placed alongside of an out-house, and should be disconnected from the sewer by a suitable trap.

The requirements of an efficient house-drain are these, viz.: (1) it should be aligned in as straight a course as possible, or with open curves; (2) it should be provided with access or inspection openings at suitable points and at suitable distances; (3) it should be laid on an even, solid bed of concrete or cement; (4) it should have a sufficient gradient; (5) all branch connections should be made obliquely and in the direction of the flow; (6) its interior should be smooth; (7) it should be disconnected from the soil-pipe by an efficient intercepting or disconnecting ventilating trap, which should not open on a pavement or close to windows or doorways.

TRAPS.

Frequent mention has been made in the foregoing chapters of traps, and from what has been said it will be rightly concluded that traps are essential parts of a system of house-drainage. When by means of circular channels the sewage and waste-water of houses came to be removed from houses to sewer, and even, indeed, before that period when square brick-built drains were in use, by reason of the discovery that foul-smelling gases passed backward through the uninterrupted continuity of pipes, it was found necessary to devise some arrangement to prevent this occurrence. This was achieved in the square brick-built drain to some extent by the dipstone trap, an arrangement whereby a flat stone placed at right angles to the flow of sewage dipped into the water of a cesspool constructed in the course of the drain, and so acted as a preventive of the passage backward of foul air from sewer to house. But when the circular or pipe form of drain was adopted, the trap had to take a new shape. Hence the most elementary forms consisted of a simple bend in the pipe, or of a depressed tongue. The above figure (Fig. 194), illustrates the "dipstone" principle adapted to the circular pipe, which was patented by Honeyman of Glasgow in 1868.

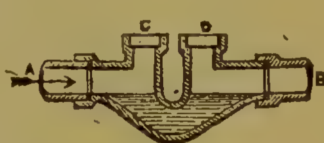


FIG. 194.—Honeyman's Trap.

Object of Traps.—The original purpose of a trap was to arrest the passage backward of the foul-smelling gases of decomposition from the house-drain or the sewer into the air of the apartment in which fittings connected with the drain by pipes were placed. Experience has shown that not only may such gases, in the absence of traps or with imperfect traps, so enter, but that foul and putrescible particulate

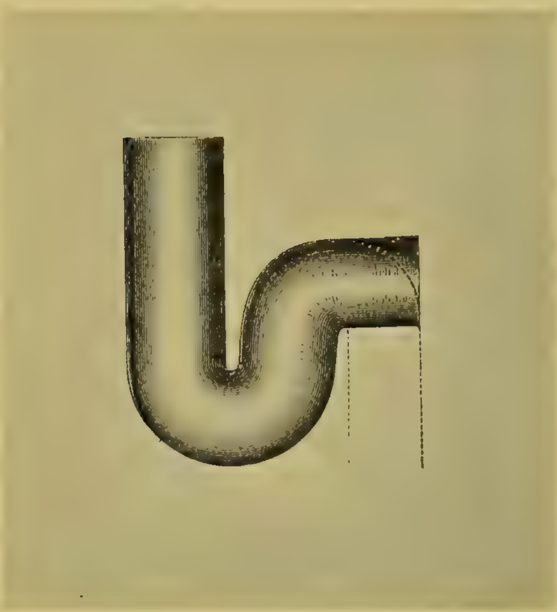


FIG. 195.—Ordinary S-Trap. The dotted lines complete the S-shape. Such a trap is fitted to kitchen sinks, etc.

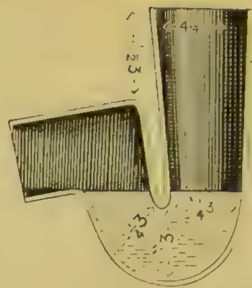


FIG. 196.—Anti-D Trap (Hellyer). The "water-seal" of the trap is the depth of the water-column between the level of the water in the trap and the point of the tongue on the upper surface of the bend.

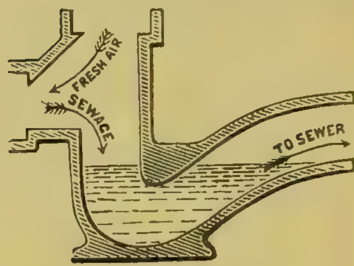


FIG. 197.

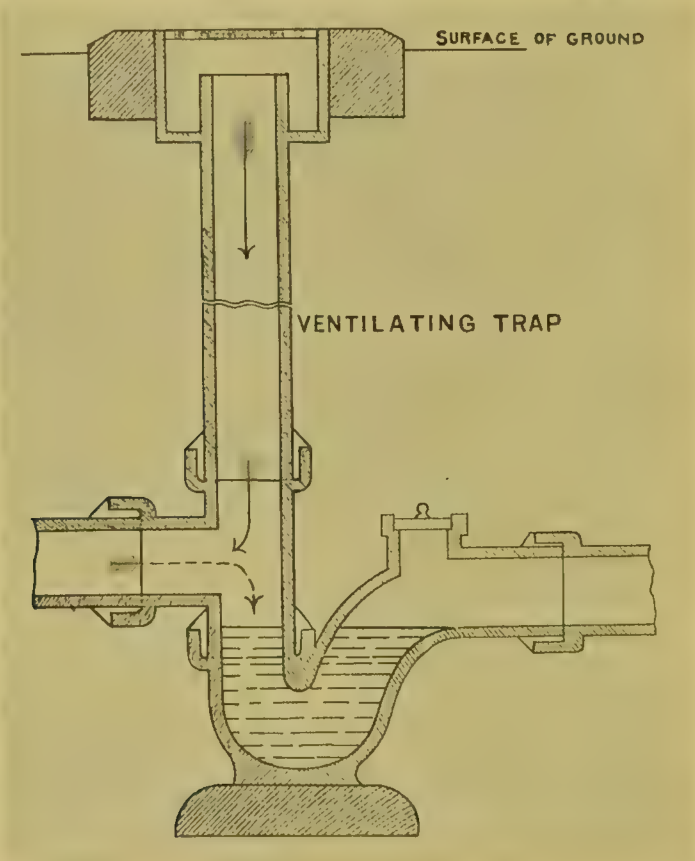


FIG. 198 shows a ventilating-trap with relation to ground-surface and flow of sewage. The ventilating-eye or opening of the trap is covered on the ground-level by a grated cover.

bodies and micro-organisms may equally pass. The medium used for the arrest of such substances is water more or less impure, and the point of arrest or trap is situated between the house interior and the

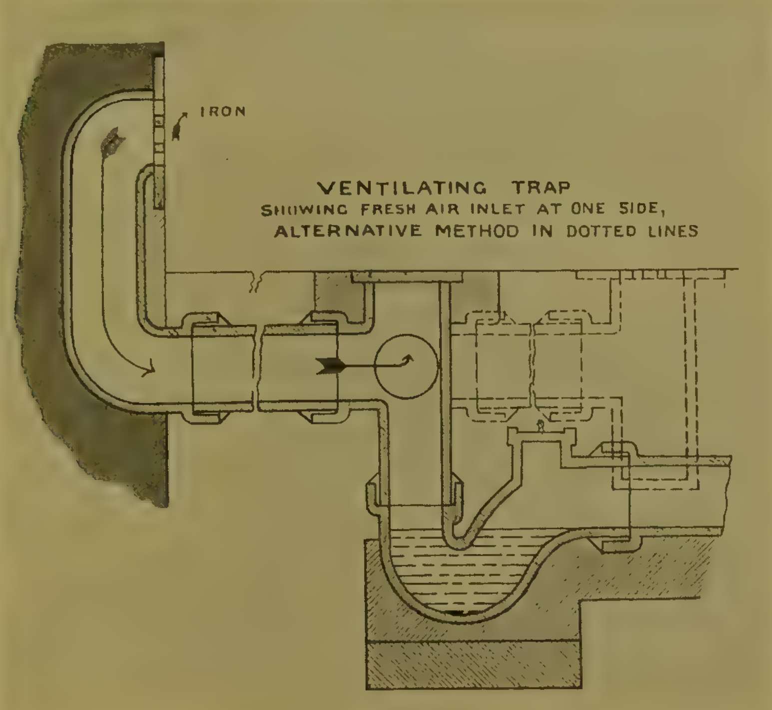


FIG. 199.—To illustrate alternative Methods of Ventilating a Trap through which Fæcal Matter passes. The ventilating opening or shaft may be raised some feet above the ground-level when most suitable, as on the left of the Figure, or it may be permitted to open on the ground-level, as shown in the dotted lines.

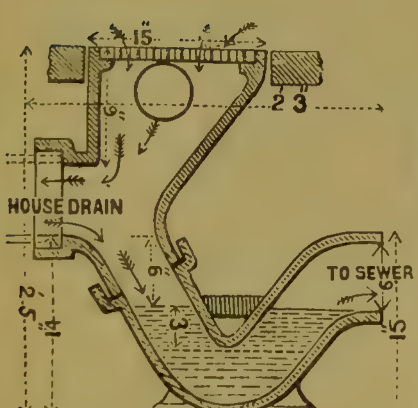


FIG. 200.

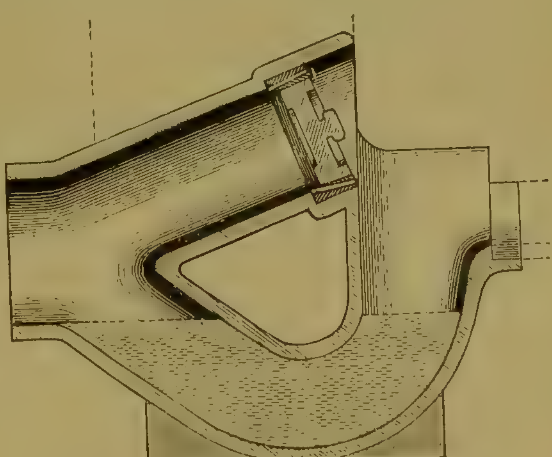


FIG. 201.—Disconnecting Trap, called the "Beancliff."

nearest adjacent fouled pipe or channel. The column of water which lies in the bend of the trap of a circular pipe (Fig. 196) is called the *water-seal or water-lock;* in other forms of traps it is the height of the

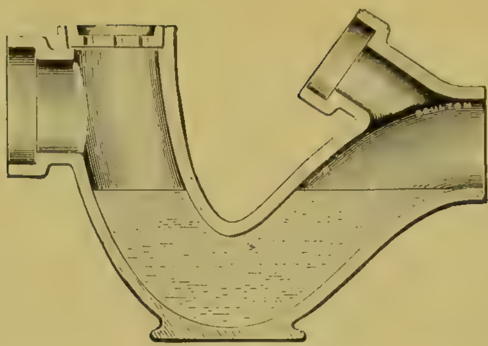


FIG. 202.—Weaver's Ventilating and Disconnecting Trap.

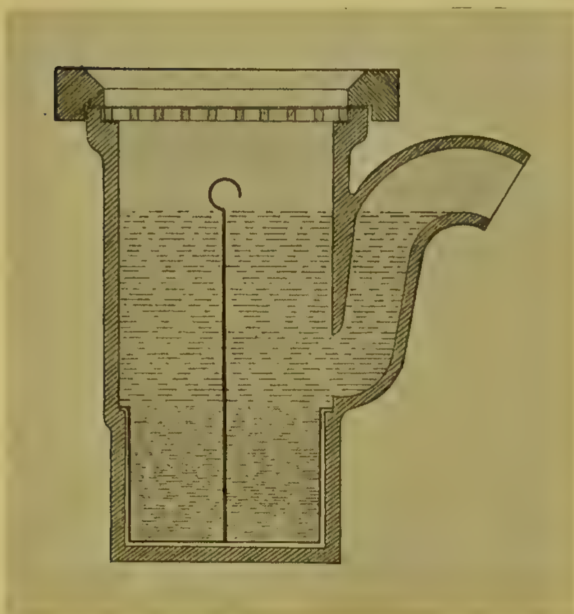


FIG. 203.—Dean's Yard Gully-Trap. It contains an iron bucket to receive the detritus, which can be emptied periodically by taking out the bucket by means of the handle shown in the Figure.

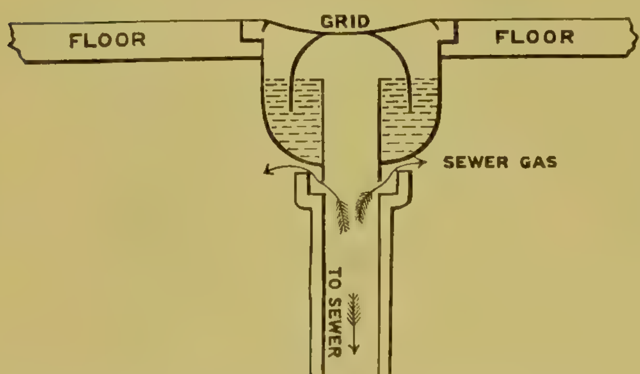
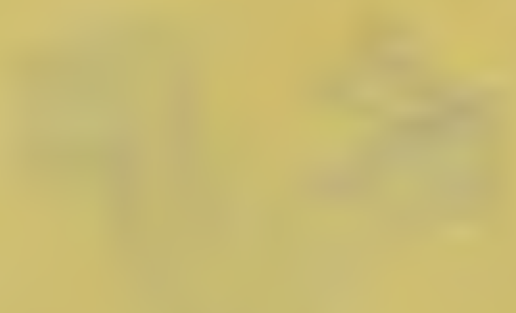


FIG. 204.—Bell-Trap—a very unsafe form of Trap, owing to the evaporation of the water unsealing the trap. It is still found in use in court-yards.

column of water from the lowest point of the "tongue" or "dip" to the level of water in the trap (Figs. 196, 197, 206).

Forms of Traps.—Traps are of different forms in respect that they are fitted to different parts of the sanitary fittings and drainage arrangements of a house and thus subserve different purposes. Those of baths and wash-hand basins consist of S bends in the pipe, with screw-plugs at the lowest part of the bend for cleansing purposes, and ought to have a water-lock of not less than $1\frac{1}{2}$ inches. In connection with kitchen sinks, since their purpose is to arrest the fatty matters contained in the outflowing water, traps are constructed of the special form shown in Figs. 165 and 166. Disconnecting and intercepting ventilating traps are fitted at the junction of waste- and soil-pipe with sewer, or at some point in the course of the house-drain. Fig. 198 represents one of the best forms of these, and Fig. 199, the same trap fitted to carry away the ventilating opening from a window or doorway. Gully traps, placed in court-yards, are constructed of forms intended to



catch surface-water containing solid detritus, as well as to prevent outward passage of drain-gases. Many forms of traps have been made by many makers for many purposes, until their number has become legion. But their uses may be said to be confined to the above purposes.

Failure of Action of Traps.—Traps may fail in their purpose from one or other of the following causes, viz.: (1) from siphon action; (2) from momentum; (3) evaporation of water-seal from disuse; (4) from silting or sedimentation, due to imperfect position. Experience with traps in connection with pipes through which water flowed with considerable velocity showed that the water-seal was liable to be forced under certain conditions; and upon investigation it was found that the disturbing cause was either difference of atmospheric pressure on the two sides of the trap, or momentum—the combined effect of velocity and weight—of the flowing columns of water. Of the causes of failure above enumerated, probably the most common is siphoning. This very readily happens, indeed is only likely to happen, where the traps themselves or the main pipes are unventilated or imperfectly ventilated.

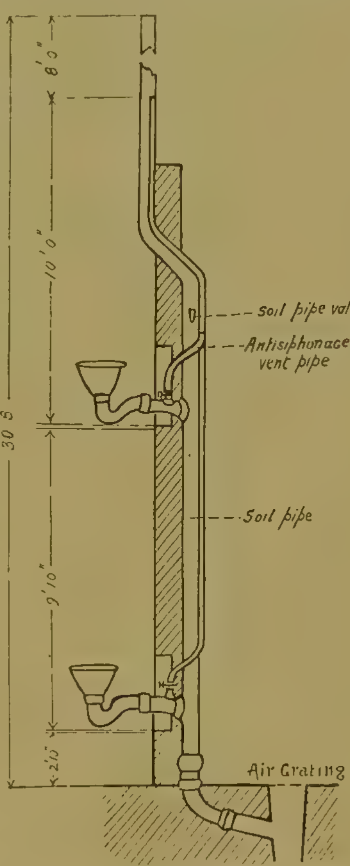


FIG. 205.—Drawing of Apparatus used in Experiments on the Siphoning of Closet-Traps, carried out by Committee of Sanitary Institute.

A valuable series of experiments bearing on the siphoning of water-closet traps has been made under the supervision of a Committee of the Sanitary Institute[1] upon apparatus fitted in the Parkes Museum. This apparatus consisted of a lead soil-pipe, 3½ in. in diameter, 30 feet 8 in. high, with two 3½-in. closet branches, one 2 ft. 10 in. and the other 12 ft. 10 in. above the ground level, each branch having a 2-in. ventilating or anti-siphonage pipe fixed at a point 9 inches from the crown of the trap. These ventilating pipes were connected and carried 9 ft. 3 in. above the upper closet branch, and were provided, as was also the soil-pipe, with valves for closing the pipes for the purposes of experiment. The closet basins were short hoppers with circular outlets, the outlet of the upper basin being 3¼ in. in diameter, that of the lower, 3½ in. in diameter. The traps used in the upper basin were (1) a cast lead "anti-D" trap, 3½ in. in diameter, with a water-seal of 2 in., and containing 40 oz. of water; and (2) a drawn-lead "Dubois" trap, 3½ in. in diameter, water-seal 2 in., contained water, 60 oz.; these used in the lower basin were (1), an "anti-D" trap, 3½ in. in diameter, water-seal 1⅞ in., contained water, 40 oz., and (2), a Dubois trap, 3½ in. in diameter, water-seal 1⅞ in., contained water, 60 oz. The water used in the experiments was poured from a pail into the basin. (Fig. 205.)

Four sets of experiments were made, viz.: (A) Water poured into upper basin, and effect produced on trap of same observed; (B) Water into upper basin, and effect on trap of lower basin; (C) Water into lower basin, and effect produced on trap of same; (D) Water into lower basin, and effect on trap of upper basin.

[1] *Jour. San. Inst.*, vol. xxii. part i. 1901, p. 88 *et seq.*

These experiments were conducted under four sets of conditions, viz.: (1) The anti-siphonage pipe open and the soil-pipe open; (2) the anti-siphonage pipe closed and the soil-pipe open; (3) the anti-siphonage pipe open and the soil-pipe closed; (4) both pipes closed. Under conditions A, B, C, D, and (1) neither of the traps were siphoned; under conditions A and (2), the Dubois trap was unsealed, and under conditions B, C, D, and (2) it was not unsealed, and under none of these conditions was the "anti-D" trap forced; under conditions A, B, C, D, and (3) both traps were intact; and under conditions A and (4) both traps were unsealed, but under conditions B, C, D, remained water-locked. It would appear, therefore, that these experiments but corroborate well-established facts, viz.: (1) that when the soil-pipe is open and a ventilating branch to the trap is provided, siphoning is prevented; (2) that if the soil-pipe be closed and no ventilating branch to trap be provided, siphoning readily occurs; and (3) that siphoning more readily takes place in the absence of a ventilating pipe to trap, although the soil-pipe be open.

Momentum is another cause which tends to unseal a trap. When the descending column of water in a soil-stack at its junction with the soil-pipe reaches an unventilated trap, it obviously has obtained considerable velocity, which is not much reduced by the water-seal of the trap; consequently since it is difficult to bring a body moving at such a velocity to a state of rest, when the last portion of the column reaches the trap, its contents are in violent agitation, and the column of water is likely to carry with it sufficient of the water of the trap to unseal it. *Disuse of traps* is another source of failure, by reason of evaporation of water-contents below the water-seal. This is liable to occur in the fittings of houses which are shut up in summer for several consecutive months, during which time the deposits in the soil-pipe and connections become also dried and powdery. By reason, therefore, of the inoperative effect of the traps in these circumstances, not only may foul gases but also pathogenic micro-organisms gain an entrance into living apartments, to give rise to attacks of illness of inmates, it may be, when the house is re-occupied. But a more common cause of this is where through carelessness, after alteration in position of certain sanitary fittings, the connections therewith have not been entirely removed, but have simply been covered over. In such a case the entrance of drain gases is bound sooner or later to be effected. Traps may further fail in their duty from being improperly set, from the effect of which, in one case, the water-seal may be opened, or in another case, sedimentation of solid matter may take place in the trap itself. This latter may also occur from insufficient flushing or from insufficient gradient of house-drain. These conditions compel different remedies, some of which are obvious. Siphoning, however, is entirely prevented by free ventilation of traps and soil-pipe. A trap is ventilated by a pipe being put on the "crown" of the trap, that is, on the soil-pipe side of the trap. Where a series of ventilating pipes are required by reason of a superposed series of fittings, as in tenement houses, they are either passed singly through the wall into the open air directly, or they are either united to a separate ventilating shaft, or joined separately to the soil-pipe at a distance above the entrance of each branch which is regulated, (1) by the maximum flush of water which is discharged into the soil-pipe at one time, and (2) by the length of soil-pipe which that amount of water will fill. One gallon of water fills a 4-inch pipe length of 22 inches, and one of $4\frac{1}{2}$ inches diameter, a length of $17\frac{1}{2}$ inches; there-

fore, if the flush from a water-closet be three gallons and the size of pipe be 4-inch diameter, then $22 \times 3 = 66$ inches will be the height above the trap at which the ventilating pipe of that branch should be joined to the soil-pipe.

In the large disconnecting or intercepting traps made of fireclay or earthenware which are placed in the ground in some part of the course of the house-drain, ventilation is obtained by a special opening

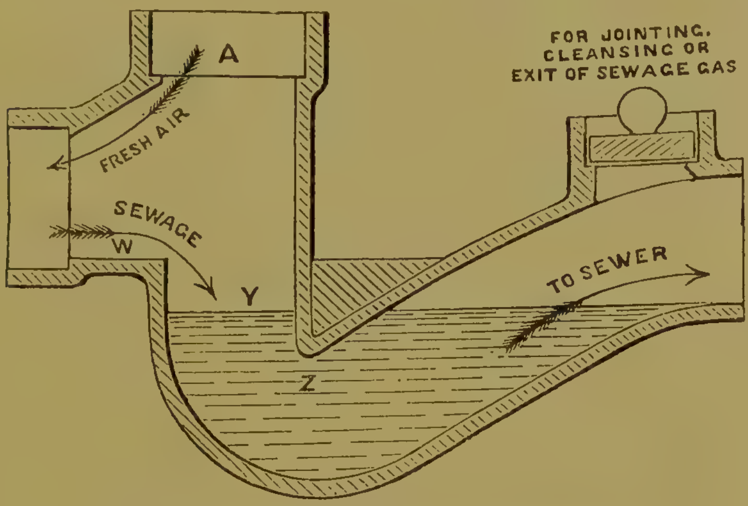


FIG. 206.—Buchan's Disconnecting and Ventilating Trap.

in the trap which reaches to the ground level, and which is of the same diameter internally as the soil-pipe or house-drain, in order to permit of free egress of air. This opening, which is on the reverse side of the trap, is usually covered by a grating. Such traps have usually four openings, viz.: (1) inlet for sewage; (2) outlet for sewage: these are horizontal openings; (3) ventilating opening; (4) cleansing or inspection opening. Of these two latter, which are vertical openings, the former is of a greater diameter and is always next to the inlet opening, so that when the trap is placed in position in relation to soil-pipe and sewer, the ventilating opening is nearest the soil-pipe, that is to say, it is on the house side of the trap. This will be comprehended better by reference to Figs. 198 and 199. In order to prevent this ventilating "eye" opening near a window or doorway, an arrangement may be provided as in Fig. 207, where this ventilating eye is carried along for some distance from the trap.

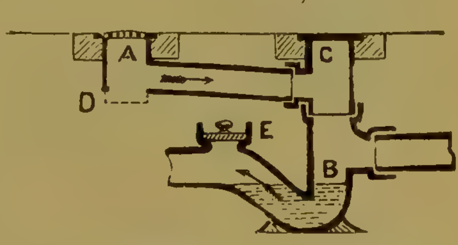


FIG. 207.—Showing mode of carrying ventilating opening of trap away from doors or windows.

The essential points of a good trap are the following, viz.: (1) it should be of a self-cleansing shape; (2) it should have an opening equal in internal diameter to that of soil-pipe for ventilation; (3) it should possess a water-seal of not less than 2 inches; (4) it should be set in a perfectly level position; (5) it should possess an opening for inspection or cleansing purposes.

Flushing of Drains.—If house-drains are properly laid, the velocity of outgoing sewage and waste-water ought to be sufficient to keep the channel free of sediment. If the house-drain be larger than required, that is to say if a 6-inch pipe has been put where a 4-inch is sufficient, sedimentation may occur, but if the proper fall corresponding to the size of the pipe has been adopted, even in such a case there is little likelihood of silting taking place. In some places, the waste-water is utilised for the purpose of flushing by being stored in a tank, which when filled to a certain point and by reason of its being suspended on a swivel, turns over and forcibly empties the whole contents into the drain. To flush a drain properly it is necessary to project suddenly into it such an amount of water as will cause it to run full-bore; it is futile to attempt this by the running of a tap or a series of them.

Testing of Drains.—While it is of importance in the case of newly-built houses that before occupancy the integrity of all the fittings for the drainage of a house should be tested and assured, it is even of greater importance that, at least annually, the test of efficiency should be repeated. Systematic attention to this would avert much disease. The modes by which fittings and house-drain are tested are these, viz.: (1) The hydraulic test; (2) the pneumatic test, (*a*) by smoke under slight pressure, and (*b*) by air itself under a higher pressure; (3) by putting some volatile odorous substance into the drain-system.

The hydraulic test is a very severe test, and when applied to pipes in the vertical position is a most unequal test, since the point of greatest pressure is the lowest, from which the pressure becomes gradually less until the highest point is reached where the amount of pressure is practically nothing. It is a much fairer test when applied to pipes in a nearly horizontal position, as a house-drain. In America, however, where waste- and soil-pipes are placed on the inside of the wall of the dwelling because of the severity of the weather in winter, special precautions are taken to secure their integrity. The pipes are heavy cast-iron pipes with leaded joints, and each length is tested by the hydraulic test when placed *in situ*. In this way, by regulating the size of length to be tested, not only may each part of the whole be tested, but a fairly uniform pressure may be used upon each part. To this mode of testing vertical pipes there can not only be no objection offered, but there is, on the other hand, much to commend its use in this country. The test consists in stopping the sewer end of the house-drain with an expanding rubber-rimmed plug, and filling the whole length with water. Should the level of the water in the trap—the point of

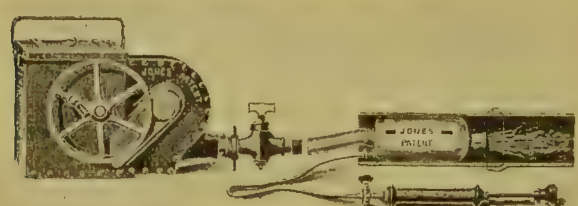
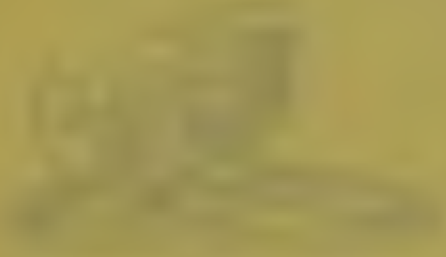
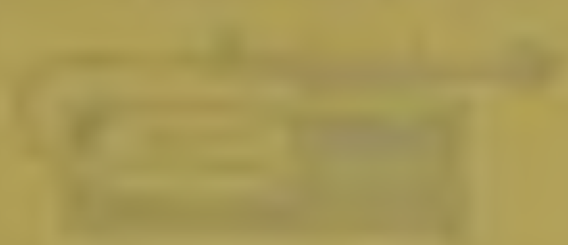


Fig. 208 represents Jones' Machine for applying the Smoke Test to Drains. By means of the hand air-pump lying in front of the Figure, the bag inserted in the Drain is inflated, and is thus made air-tight. The Bag is constructed so that the smoke-pipe from the machine passes through it into the Drain, and so the Drain or Pipe may be filled with smoke.





observation—fall, it indicates faulty construction, provided that no leakage is occurring at the point of plugging. The pneumatic test by smoke can be applied to most buildings at any time. It consists in filling the whole sanitary apparatus with pungent smoke generated from sulphur and oily waste cotton, under some degree of pressure. The amount of pressure, however, is very small, but is sufficient to detect substantial flaws in piping which are difficult of detection by simple inspection. In order to conduct the test it is necessary to hermetically close the top openings of waste-pipe and soil-pipe, where the waste-pipe is connected underground with the house-drain by means of a trap. The smoke is driven into the ventilating opening of the trap, which is closed by clay round the

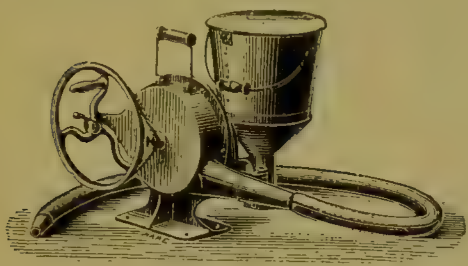


FIG. 209.—Another form of Smoke-testing Machine.

FIG. 210.—Bag Drain or Pipe Stopper for testing Drains or Pipes by smoke, pneumatic, or hydrostatic test. (Burn Brothers' Patent.)

inlet smoke-pipe from the smoke-generating apparatus. In the event of there being any points of leakage in pipes or fittings, the presence and odour of smoke at these points will indicate them. The apparatus used is called a smoke-testing or fumigating machine, and it consists of the following essential parts, viz. : (1) The motive power by which the smoke is propelled into the house-fittings; (2) the smoke-generating receptacle; (3) rubber - tubing to connect these, and also to connect the latter with the ventilating opening of trap. The motive-power in most machines is by hand-working a fan which propels the smoke, but in Fyfe and Dobson's apparatus the motive-power is the automatic action of spirting jets of water.

FIG. 211.—Pipe-Stopper inflated by air-pump to close drain-pipe.

By means of a side-opening, the Fyfe-Dobson apparatus is connected with the service water-pipe from the main-pipe. When the jet of water enters the cone-shaped part, in the upper part of which the smoke-generating material is placed and lighted, it is split into a large number of fine spirts or sprays, which cause a current of air and smoke to be propelled into the drain to be tested. The advantages of the machine are its saving of hand-labour, its automatic action, and depending upon the pressure of the water-supply, a higher smoke pressure.

The main objection urged against the smoke test is that the pressure of the smoke is insufficient to detect such defects in pipes or fittings as will admit foul air, either from defective workmanship, or from defective material; in other words, that although on application of this test no leakages are discovered, it is no certain proof of the tightness of the drainage system. Another objection is that unless the leakage is substantial, it is apt to be overlooked by the careless or negligent observer, since minute inspection of each pipe and fitting during the currency of the test is necessary and essential. For these reasons, therefore, it has been strongly urged to substitute air under compression for smoke. The advantages and merits of the air-test urged by its advocates are these: (1) It gives a positive result; (2) it can be applied to any building and the pressure be made uniform; (3) it can be applied to covered or uncovered pipes; (4) it is easy of application; (5) the pressure can be regulated from a fraction of an inch of water up to a number of feet of water; (6) leakages are discovered by a fall occurring in the manometer at the point of operation. Against its use, it has been urged that although leakages may be proved to exist, they are more difficult of detection because there is no visible or olfactory evidence of their location as in the smoke test, and therefore, in the end, recourse must be had to the smoke test. To Gilbert Thomson of Glasgow must be ascribed the merit of introducing and showing the value of the pneumatic test as a proof of substantial workmanship and excellence of quality of material. The apparatus which he has devised for the test may be described as follows:—It consists of (1) an air-pump; (2) a valve; (3) a manometer or gauge; (4) a brass T-piece; (5) some yards of rubber tubing. By using water in the manometer pressure up to four inches, and by using mercury, a pressure of 4½ feet of water may be attained. Defects in the sanitary fittings are betrayed by the falling of the manometer on the pumping-in of air being stopped.

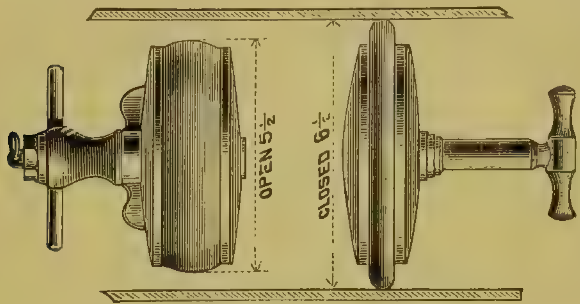


FIG. 212.—Jones' Expanding Screw for Stopping Drain or Pipe, in smoke, pneumatic, or hydrostatic test.

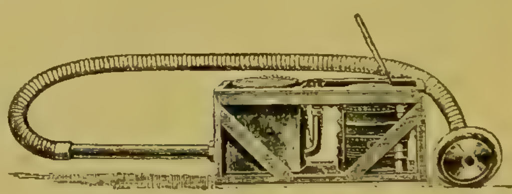
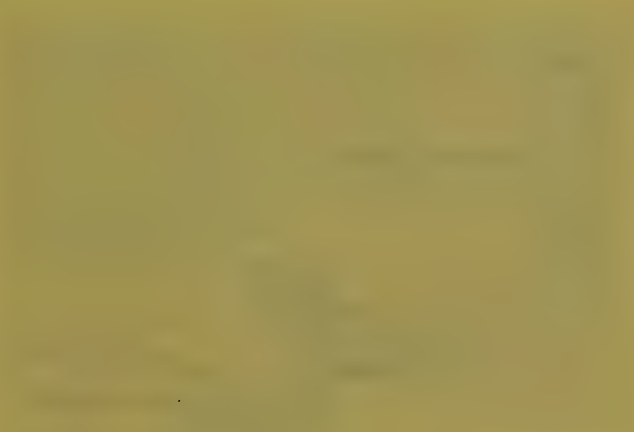
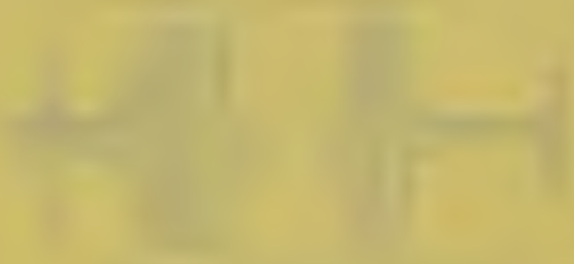
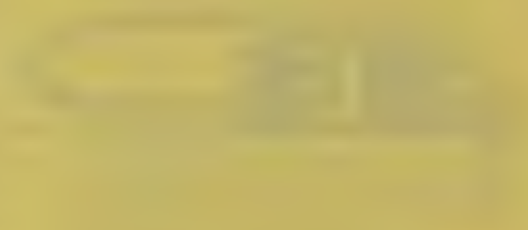


FIG. 213.—Smoke-Testing Machine. On the right is the bellows, and on the left the smoke-generating receptacle, out of which passes the tubing for connecting the whole apparatus with the drain attachment.







The use of odorous substances, such as oil of peppermint followed by hot water, has been advocated for buildings of old standing in the drainage system of which there is no disconnecting trap or chamber. Apart from the inefficiency of such substances to detect any other than very substantial or gross flaws, the very fact that no disconnecting apparatus exists ought of itself to condemn the system as insanitary and dangerous to health. In such a case the drain should be opened and the smoke test or pneumatic test applied after a disconnecting trap has been introduced.

Plan of Drains.—The Public Health (Scotland) Act, 1897, section 181, gives power to Local Authorities to make bye-laws respecting the production of plans with reference to the proposed system of drainage of new buildings. Glasgow, Aberdeen, Dundee, Greenock, and local authorities of other burghs demand the production of such plans to scales laid down. A good scale is that adopted by Aberdeen, viz.: $\frac{1}{8}$ inch to the foot. Section 120 of the same Act, and s.s. 238 and 239 of the Burgh Police (Scotland) Act, 1892, enact that no building shall be erected until a sufficient drain or sewer has been constructed from a common sewer to a point opposite the proposed building, provided that a common sewer exists within 100 yards of the proposed building, or until the Local Authority is satisfied that a proper channel for sewage can and will be provided. An exact plan of the drainage system of every occupied building should be possessed by the owner. Such plans at first sight seem complicated; but they may be quickly understood. Much unnecessary expense and trouble are saved by such plans (*vide* Figs. 184, 189).

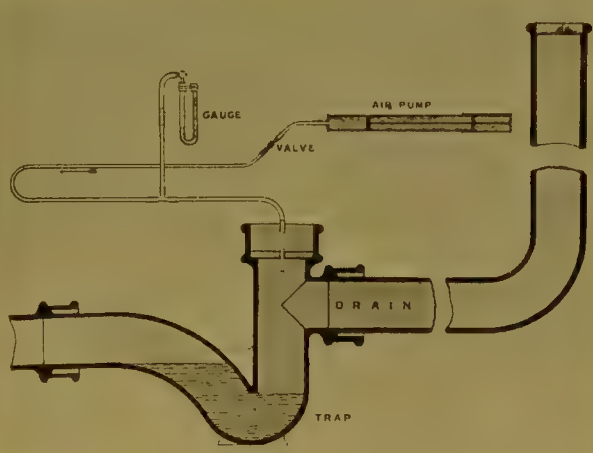


FIG. 214 shows Gilbert Thomson's Mode of Testing Drains by Pneumatic Pressure. By means of the air-pump any air-pressure, up to a reasonable amount sufficient to test the integrity of workmanship and material, may be employed. The amount used is indicated by the manometer or gauge. By the steadiness or fall in level of the manometer is the integrity or faultiness of the fittings determined.

Disinfection of Drains.—It is neither simple nor easy to disinfect, in the true sense of the word, a drain, and much less a sewer. To achieve scientific disinfection would be both laborious and costly. The fashion of adding disinfectants in small quantities is simply a delusion, because of the degree of dilution which these undergo. Certain disinfectants as corrosive sublimate, chlorinated lime, and others, which are passed into soil-pipes with this object, attack the metal of the pipes, the first acting especially as a solvent of the solder. The best and cheapest disinfectants, which, moreover, are secured by efficient ventilation of traps

and pipes, are fresh air and a plentiful supply of water. If all channels are well flushed with both of these, there is no need for attempted chemical disinfection.

Before leaving the subject of house-drainage, the term "house-drain" ought to be defined in order to distinguish between that channel and the sewer. A house-drain may be said to be that channel which receives the waste-water, rain-water, and excretal products from one building; the sewer, that channel which receives these products from several buildings by way of the house-drains. It is for this reason that in Scotland the sewer is usually called the *common* sewer. The Public Health (England) Act, sec. 4, defines a drain as "any drain of and used for the drainage of one building only, or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed"; and a sewer, as including sewers and drains of every description except drains to which the word "drain" interpreted as above applies, and except drains vested in or under control of any authority having the management of roads and not being a local authority under this Act. In the Metropolis Local Management Act, 1855 (18 & 19 Vict. cap. 120, sec. 250), the word "drain" is held to "mean and include any drain of and used for the drainage of one building only or premises within the same curtilage, and made merely for the purpose of communicating with a cesspool or other receptacle for drainage of two or more buildings." In Pilbrow *v.* St. Leonard's Vestry, Shoreditch (*Times*, Nov. 3, 1894), the question in dispute was whether, in artisans' dwellings consisting of two blocks of forty-six sets of apartments draining into a common drain by twelve branch drains, the common drain was a drain or a sewer in terms of section 250. The Court held that the "common drain" was a drain and not a sewer, and that the premises were one curtilage. There is no definition of drain or sewer in the Public Health (Scotland) Act, 1897, or in any other Public Health Act relating to Scotland. In the Glasgow Buildings Regulations Act, 1900, "drain" means any drain or pipe which connects the waste- or soil-pipes or conductors of a building or buildings with a sewer or cesspool.

Sewers.—These channels which receive the sewage from the drains of houses, and, usually also, the rainfall, street-washings, and effluents from trade processes, commonly run in the centre of street or roadway. They are like the veins of the circulatory system, in respect that their size becomes larger as the outfall is neared. In any particular case, the sewer must not only be made large enough to carry away a present total estimated amount of sewage, but also to include a future possible increase. Their shape is either round, oval, or egg-shaped, the best shape being the last-named, since it offers the minimum amount of friction to velocity of flow, and as the volume of flow becomes diminished this resistance is proportionally reduced, whereas in the circular form, on reduction of volume of flow the resistance is relatively increased. The points to be aimed at in the construction of sewers are as follow: (1) To ensure uniform and constant velocity of flow; (2) To secure by sufficient gradient such velocity of flow as will remove

solids but will not unduly wear brickwork of sewer; (3) To prevent sedimentation and deposition of solid material at junctions; (4) To minimise back-watering as much as possible at the outfall on tidal rivers; (5) To secure by ventilation the greatest possible purity of air of sewer; (6) To prevent by like provision the forcing of house-drain traps or other traps of houses. The velocity of flow in sewers should not be less than 2 or 3 feet nor more than 4 to 5 feet per second, because such mean velocity will effect removal of solids without undue prejudice to brickwork. The fall in sewers should be 1 in 240; where the gradient is less, deposits are apt to form. It happens, however, in exceptional circumstances that such a fall as the foregoing cannot be obtained with relation to the position of the most suitable place for disposal of sewage into the sea or for purification. In Brighton, for example, the fall is only about 3 feet per mile, or 1 in 1760. In other districts still more level, and where a proper sewer gradient cannot be obtained without very deep cutting or tunnelling, it is better and cheaper to adopt the Shone system, in which by means of his patent ejectors worked by compressed air from a central station, the sewage is lifted from one level to another, each section of sewering being laid with a proper fall, thus utilising all the assistance which gravity is able to give. The ejector is a cylindrical reservoir having an inlet and an outlet pipe for the entrance and exit of the sewage, each pipe being provided with a ball valve, and the inlet pipe having the shape of a siphon. By means of tubes which are conducted along the upper flat surface of the exterior of the reservoir, compressed air is injected by the automatic action of a float on a counterpoised lever which opens the air-valve. This float rises as the reservoir fills with sewage, and at a given height sets this mechanism in operation. The effect of the admission of compressed air is to close the inlet valve, liberate the outlet ball valve, and to drive or eject the sewage out of the reservoir by means of the outlet pipe into the section of sewers at a higher level, by which it flows by gravity into the next ejector, and so on until the outfall is reached. It is claimed for the process that two such ejectors, each of a capacity of 100 gallons, are separately capable of raising 75 gallons of sewage to a height of 50 or 60 feet, and that they suffice for the convection of the sewage and rainfall of an area of 2000 inhabitants. This system has been in operation since 1896 in Arad, Hungary, and disposes of the sewage of 20,000 persons by means of five ejector stations; as also in Rangoon.

Ventilation of Sewers.—In some populous places as Bristol, the sewers are unventilated; and it is alleged that the only time when complaints of smells arise in that city is after prolonged drought when the gully-traps become dry. Statistical evidence of those diseases attributable to sewer influence shows no excess of mortality in that city. In most towns and cities, however, the sewer system is ventilated by means of gratings situated in the roadway, while in a smaller number of populous places special ventilation-shafts are substituted for the gratings. In the Brighton system, the main outfall sewer, and to some extent the town sewers are ventilated by means of a furnace and tall chimney placed at the outfall. The gratings referred to are placed at distances of from 40 to 100 yards apart, and there is little

doubt that an interchange is effected between the air of the sewer and of the outer atmosphere. The ventilating action is, however, fitful and variable; some of these gratings act at one time as outlets, and at others as inlets, while at another time their action respectively is reversed, the incidence of their action depending upon local air movements, and the admission of hot water or spent steam at given points into the sewers. There can be no doubt that ventilation of sewers is necessary, but the best plan to attain this can only be decided by local circumstances. Whether the time will come when the sewer system of towns and cities will be ventilated as carefully as the interior of inhabited dwellings, hospitals, or other large buildings, it is difficult to say, but there is no doubt that the present mode of ventilating into streets and roadways exercises prejudice, in some measure, to the public health. It would be an infinitely superior method to the roadway gratings to ventilate by tall shafts placed at suitable points, from which a current of air could be drawn through the sewers by the motive power of a furnace and tall chimney erected at the outfall works.

Sewer Air and Sewer Gases.—It is universally admitted that the respiration by persons of an atmosphere containing an admixture of sewer air and sewer gases is productive sooner or later of illness. Since drains and sewers carry fluids in an active state of decomposition, foul-smelling gases, consisting chiefly of compounds of sulphur with hydrogen or ammonia, are bound to be given off. That the inspiration of air largely contaminated with these gases is fatal to human life has been proved on not a few occasions in London, Glasgow, and elsewhere, by deaths of workmen in sewers. From constant exposure to much smaller quantities ill-health is occasioned, as shown by loss of appetite, malaise, debility, anæmia, and, sometimes, by eruptive skin diseases, as boils, etc. The composition of sewer air obviously depends upon the measure of free ventilation which exists, and this factor must be held to account for the great differences found in analyses of such air. Reduction in volume of oxygen and increase in volume of carbonic acid and hydrogen sulphide seem to be the outstanding characteristics of sewer air, and the respective amounts of these would appear to depend upon the ventilated or unventilated condition of the sewer from which the air-samples are drawn. In addition, however, to these malodorous gases, there are others which possess a faint, sickly, or fœtid odour, and which appear to be composed of compounds of carbon and ammonia and carbon and hydrogen. Of greater importance, perhaps, than these, are the micro-organisms of sewer air of the pathogenic type. Despite the researches of Laws and Andrewes on the micro-organisms of sewage and sewer air, micro-organisms of disease must sometimes pass from sewers with the air. It is established that air cannot take up organisms either from a column of liquid or from a wetted surface, but it is equally well proved that air can dislodge them from a desiccated surface, else conclusions respecting air-borne infection of tuberculosis from dried sputum are wide of the mark. Therefore after long periods of drought, when the upper sections of sewers become dry, it is not difficult to conceive that bacilli and spores might be carried in the sewer air. This question

demands still further investigation over long continuous periods before dogmatic conclusions can be formulated. It is difficult to disassociate in the mind as cause and effect the continued ill-health of families in houses, as exhibited by sore throat, diphtheria, and enteric fever, and the discovery of a corroded and perforated soil-pipe in the interior of the dwelling. Further, it has often been remarked in populous centres that filth diseases are less prevalent in a wet than in a dry summer and autumn. While, doubtless, other factors have an influence in the causation of these, the effect of dry-walled sewers cannot be left entirely out of count.

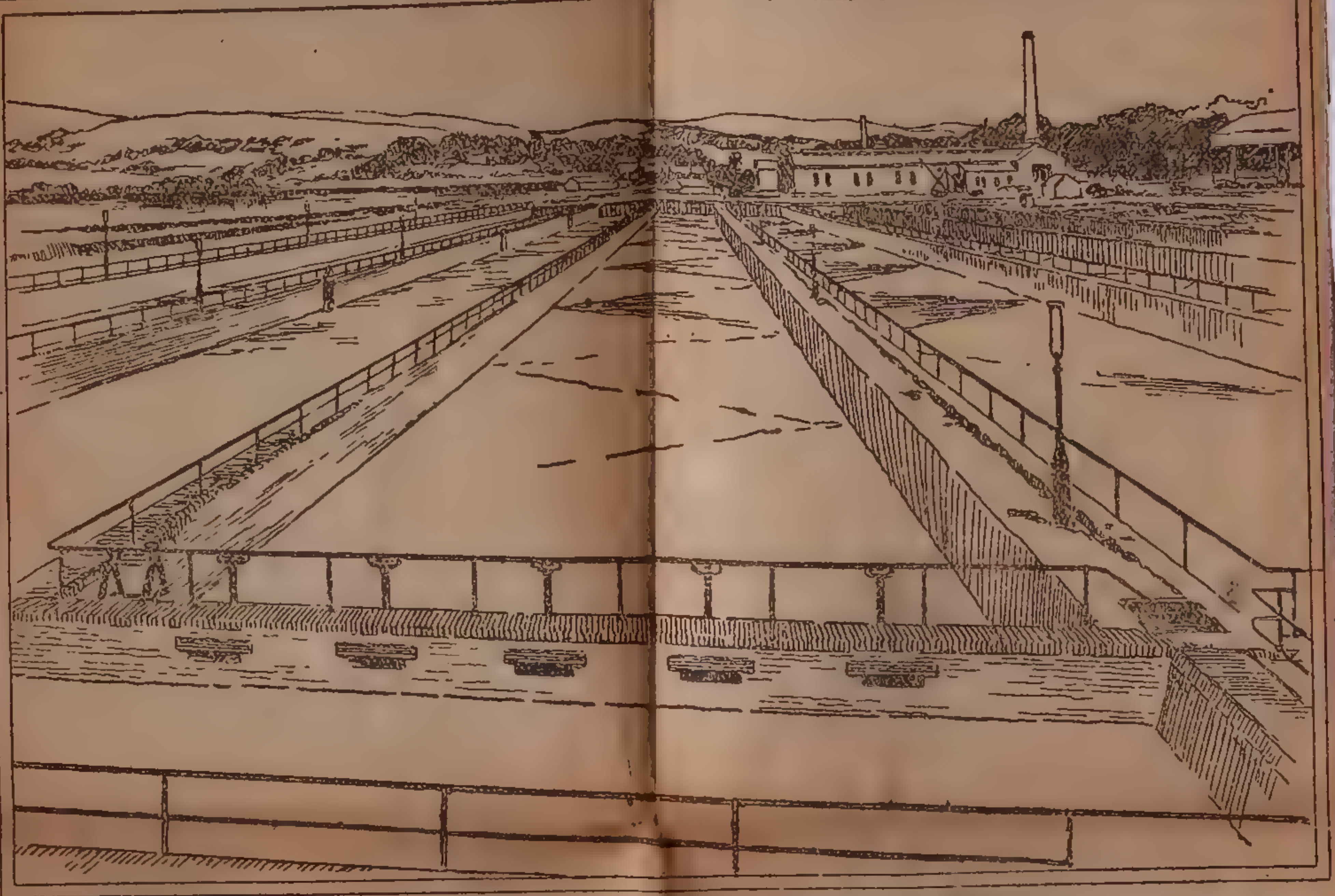
Mode of Conducting an Investigation into the Sanitary Efficiency of a Dwelling.—This resolves itself into different lines of inquiry, depending upon the scope or limits of the investigation and the objects for which such an inquiry is demanded. If the object of the inquiry is whether a house, or part of a tenement building is or is not fit for human habitation, attention must be devoted to (*a*) *structural deficiencies*, in the form of dilapidation of walls, ceiling, floor, the presence of dampness, etc.; (*b*) *deficiency of light;* (*c*) *absence of means of ventilation* and the impossibility of establishing through ventilation in underground rooms; and (*d*) *absence of adequate arrangements for disposal of night-soil and household waste.* Where, on the other hand, the object is to discover the integrity of the sanitary fittings in connection with a water-carriage system of disposal of sewage, a more restricted line of investigation is called for. In the first place, each sanitary fitting and its connections within the dwelling must be inspected to see if each possesses a suitable trap, and in the case of the closet-fitting, whether the water-flush is sufficient or not, and what is the form of the closet relative to efficiency. It is important at the same time to note the condition of the water-closet apartment with respect to possibility of ventilation, and its position with relation to the other apartments. Thereafter the external fittings should be inspected so far as is possible from the ground-level. The points to be noted are: (1) whether or not the soil-pipe is carried for at least a distance of three feet above the eaves, and its position relative to windows; (2) whether the waste-water system is separated from the soil-pipe system; (3) the mode of connecting main waste-pipe and soil-pipe with house-drain, and the presence or absence of traps at or near the points of junction; (4) the general plan of drainage and course of drains. Thereafter, the integrity of the pipes and fittings must be tested either by the smoke or pneumatic test. The effect of both tests has been already described, but the mode of applying the smoke test must be explained more fully. The first step to be taken is to cover the upper extremity of the soil-pipe with a slate luted with clay, so as to make it air-tight, and also the upper end of the main waste-water pipe, if both main pipes be controlled by the same trap beyond their junction with the house-drain. Then the ventilating eye or opening of the disconnecting trap is uncovered, and the exit pipe of the smoke-generating machine is fitted into it, and luted well round with wet clay so as to make it also air-tight. When this is accomplished, smoke is driven into the pipes until they are completely filled under some pressure, as shown by its presence in the upper extremity of the soil-pipe or waste-pipe on momentary removal of luting material. At this stage each apartment in which a fitting is placed—bath, sink, wash-hand basin, water-closet, or urinal—is examined for the odour or appearance of smoke, and the soil-pipe and waste-pipe on the outside wall are scanned for evidences of emission of smoke, and if such be found, they are noted. In the event of neither odour nor appearance of smoke being discoverable in any of the apartments, and if no smoke be seen to issue from the main-pipes *after careful examination*, it may be reckoned that no definite breach of pipes exists. If, on the other hand, odour of smoke be discovered in any of the apartments, careful search must be instituted until the source of leakage is discovered. Thereafter, the deficiency must be remedied. The pneumatic test is more searching, however, than the smoke test, and it is calculated to discover not only definite breaches in the pipes and defective workmanship, but also defective material which might not be detected by the smoke test. The advantage of this test over the other is that varying

degrees of testing-pressure may be employed. The mode of application is exactly the same as the other, and so is the place where the air-pump is applied. Leakage is indicated by the gradual lowering of the pressure in the manometer, and the degree of defect in the pipes by the rapidity in fall of the pressure, or by the pressure-gauge refusing to rise. The practical difficulty, however, now arises as to the situation of the leak or leaks, which, obviously, can only be discovered by the hissing or sibilant sound which air escaping under pressure from a small opening is likely to cause. This, however, is likely to be absent where, for example, defect in the internal structure of a cast-iron pipe, such as defects in casting, is the only cause of the lowering pressure. In such cases, the smoke-test would be of little value, because the pressure is insufficient in ordinary circumstances to reveal the defect. It may happen, however, that the cause may be found in minute defects of joints, or in pin-hole openings in the continuity of pipes, or in cracks at bends. The sanitary fittings of a dwelling ought to be so perfect when first installed that they will stand some inches of pressure by the pneumatic test. It is quite obvious that if the various traps of sanitary fittings are ventilated into a special ventilating shaft, that it, in addition to soil-pipe and main-pipe, should also be closed air-tight at its upper extremity during the test. Where a tenement of houses is being examined, attention must be paid to trap-ventilation with reference to siphoning of traps on a soil-stack, or main waste-water stack.

It may be necessary to conduct an inquiry into the condition of a house with reference to ground-damp and dampness in walls. Ground-damp and wall-dampness usually arise from absence or inefficiency of damp-proof courses in walls and from the absence of an impervious layer, such as asphalt, between flooring and ground-level. In such cases removal of planks of flooring at different points of the apartment will reveal the true state of affairs, and digging down to the foundation of the wall of the building on the outside, the existence or absence of a damp-proof course. Examination of the flooring and joists at the points where the planks are uplifted, will show the presence or absence of dry-rot, which is a fungus which quickly grows in darkness, although it only fruits in the light. It quickly spreads along the timbers, permeating the wood in such a manner that planks sometimes can be broken by the hands. A plank so affected looks warped, is dry and cracked, and may or may not exhibit fungus on its exterior. While dry-rot is commonly an indication of deficient under-floor ventilation, it is also due—and this is probably the most common reason in new houses—to the use of imperfectly-seasoned wood. We have seen the whole woodwork of an apartment ruined by this fungus within a year after its construction, due to this cause. In the examination of country-houses all the above points must be attended to, and, in addition, the mode of sewage-disposal.

THE GLASGOW SEWAGE SCHEME.

WESTERN DISTRICT SECTION.



VIEW OF THE PRECIPITATION TANKS, LOOKING NORTH.

INAUGURATION CEREMONY.

The Western District section of the Glasgow main drainage scheme was formally inaugurated yesterday. The works, which are situated at Dalmuir, have already been described in the "Herald." Their construction has occupied a period of five years, and their opening signalises the completion of the major portion of the scheme for the city which, next to the undertaking of the London County Council, is the largest of its kind in the world. On the invitation of the Lord Provost and the chairman and members of the Committee on Sewage Disposal of the Corporation of Glasgow a large company, representative of the city and of neighbouring local authorities, attended the ceremony yesterday. They were conveyed from the city by a special train, which left the Central Low Level Station at noon, and Dalmuir was reached about 25 minutes later. Fully an hour was spent in an inspection of the vast undertaking, and at half-past one o'clock the works were formally inaugurated. For this ceremony the company were grouped upon an embankment overlooking the precipitation tanks, where they were photographed. The four sluice valves were then opened simultaneously—one each by the Lord Provost, Sir John Ure Primrose, Bart.; Councillor Robert Anderson, convener of the Sewage Disposal Committee; and Bailie P. G. Stewart, and Councillor Warden, the sub-conveners of the committee. The operation occupied only a few seconds, and its completion was followed by prolonged cheering.

THE LUNCHEON.

Luncheon was served in one of the spacious halls connected with the works, the interior being tastefully decorated for the occasion. The Hon. the Lord Provost occupied the chair, and the guests included, among others, Provost Kennedy, Partick; Councillor Robert Anderson, Mr A. Wylie, M.P.; Rev. W. Swan, Mr Nathaniel Dunlop, Mr Thomas Mason, Sheriff Lees, Sir John Shearer, Mr G. Midgeley Taylor, Mr A. B. M'Donald (city engineer), Bailie Sorley, ex-Preceptor Dickson, Bailie John Taylor (Clydebank), Mr W. M Killop, M.P., Mr W. R. Copland, Mr Hugh Brown, Treasurer M'Cutcheon, Mr W. D. Bell (of Messrs D. Stewart & Co.), Bailie Dunlop, Mr Thomas Watson, Preceptor Mitchell, Mr [illegible] Mitchell, Mr [illegible] H. Morton, Mr J. R. Mackenzie, of the Clyde Trust, Mr R. M. F. Watson, superintendent Western Division, Caledonian Railway, Mr James G. Moure, Town-Clerk, Mr John Lindsay, Police-Clerk; and Mr Lennox M. Sellar. The croupiers were Bailie P. G. Stewart, Councillors Warden, W. F. Anderson, and John M'Farlene. After luncheon, the loyal toasts were given from the chair and duly pledged.

Presentation to Lord Provost.

Mr Robert M'Alpine, jun., on behalf of the contractors, asked the Lord Provost to accept a five light silver candelabra, of elegant design and workmanship, as a souvenir of the occasion. In doing so, he remarked that it had been a great pleasure to all concerned to be associated with such an important undertaking, which was to prove so beneficial to the community.

The Lord Provost, in accepting the gift, said that it would ever be associated with one of the most momentous events in the history of Glasgow.

Houses of Parliament.

Preceptor Mitchell proposed "The Houses of Parliament." He said that the House of Lords was actuated by a desire to do the best for the

on which the sons of to-day were building. (Applause.) There were also present others, some of whom had occupied the convenership of the Sewage Committee, and they could not help ransacking their reminiscences and remembering that to Mr John Carrick, their respected and trusted city engineer, they owed the inception of the sewage scheme of Glasgow. (Applause.) For fifty years it had been floating in the minds of people as a more or less nebulous or nebular proposition, and it was only when we had a particularly hot summer and the aroma of the Clyde became particularly pungent that public feeling for a time was stirred, and schemes more or less practicable were put before the community. But Mr John Carrick recognised that in the operations of the Caledonian Railway Company, in connection with their Central railway, a large section of the sewage of the city could be brought to a treating point without the Corporation being involved in any considerable expenditure. It was owing to his wise foresight and guidance that that scheme had been carried to a successful termination, and that out at Swanston Street they had been able to demonstrate unmistakably that the foulest sewage of the city could be satisfactorily treated, and that in every object-lesson given in those works they had hope for the dawn of a day when a measurably pure river might run through the city. (Applause.) That experience had received its further development in the works which they were now inaugurating, and as they spoke of Mr John Carrick of the past they could also speak of his successor, Mr M'Donald—(applause)—who, aided by the consultative ability of Mr Copland, of the late Mr Santo Crimp, and of Mr Midgeley Taylor, had brought to fulfilment that section of the undertaking, which, he ventured to predict, would prove worthy of the engineer who had devised it and the contractors who had executed the works. (Applause.) They had only to mark time for other three years or thereby, and then, with the scheme for the south side of the city completed, and when they had removed all reproach in the matter of pollution of the Clyde from their own doors, they could justly demand that every other public body whose sewage entered the river should be placed under the same obligation under which Glasgow had placed itself to cease to be a source of contamination and pollution. (Applause.) It was a happy circumstance that they had that day with them representatives of many Local Authorities down river, who had joined the confederation of purification, and had cast in their lot with them in the scheme, an important part of which they had that day inaugurated. In whatever lay before the Corporation, he hoped that [illegible] they undertook [illegible] the [illegible] and he hoped [illegible] all their further adventures would be d[illegible] and consecrated to the service of humanity in the direction of making life healthier, [illegible]er, and more enjoyable from the physical point of view. (Applause.)

The Sewage Undertaking.

Mr Robert Crawford, LL.D., in proposing "The Sewage Undertaking," congratulated the committee, and especially the convener, Mr Robert Anderson, on the successful way in which the work had been carried out, and anticipated a great success for the scheme when it is completed. He recalled the early stages of the movement for the purification of the river. This scheme, he said, was very different from such enterprises as the provision by the Corporation of tramways, gas, water, and the cleansing of the city. These were all positive and definite, and most of them offered a source of revenue. But in regard to the purification of the river they had something which was illusive, indeterminate, [illegible]thetic; and Glasgow, in setting its hand to this undertaking with patience, determination, courage, and perseverance, had done one of the most meritorious [illegible] things the city had

gineer; Mr Thomas Mason, and Mr Bell (of Messrs D. Stewart & Co., Limited).

Mr Taylor, in replying, said that he did not consider one penny was being wasted in an attempt to produce an effluent better than was required for the River Clyde.

Mr M'Donald said that it was a great honour and privilege, and would be a life-long satisfaction to him, to have his name associated with this undertaking. Now that the larger part of the scheme had been carried to a satisfactory conclusion, he looked forward with confidence to the completion of the remainder at no very distant date.

Mr Morton said they were all sorry that the late convener of the Sewage Committee, Bailie James M. Thomson, had not been spared to take part in the ceremony.

Mr Thomas Mason said that, as the first convener of the committee, it was exceedingly gratifying to find that the lines originally laid down were being followed. He congratulated the Corporation upon the progress they had made, and expressed the hope that the time was not far distant when the prophecy of the Lord Provost, that we would have salmon at the Broomielaw Bridge, would be fulfilled.

Mr Bell said that all the contractors were deeply sensible of the honour and privilege of assisting in the accomplishment of this great scheme.

The proceedings terminated, and the company returned by special train to the city.

The Machinery at Dalmuir.

The buildings which contain the sewage treatment machinery are very extensive, and are situated north of the precipitation tanks. They comprise the main power-house, 80ft. long by 34ft. 6in. span; the main pump-house, 89ft. long by 30ft. span; the boiler-house, 78ft. long by 51ft. 9in. span, with coal store and economiser-house attached; the main chemical houses, 96ft. long by 45ft. 6in. span each; and the catch pit-house, 150ft. long by 34ft. span, with screen-house and loco. shed attached. Adjacent to the main buildings are the men's room, baths and lavatory accommodation; and to the north of the machinery buildings are the repair shops, joiner shops, smithy, and store, with the general offices, committee-rooms, and laboratory. The centrifugal pumping plant required to raise the Clydebank sewage consists of two compound centrifugal pumping engines, each capable of lifting 4000 gallons of sewage per minute through a net height of 20ft., and one triple compound centrifugal pumping engine, capable of raising 9000 gallons of sewage per minute through the same [illegible] two [illegible] engines, each capable of delivering 300 el. h.p. and one similar generator, capable of delivering 150 h.p. These engines, together with the centrifugal pumping engines, are connected to two independent direct steam-driven surface-condensing plants. The boiler plant consists of four Lancashire boilers, 7 feet 6 inches by 30 feet, suited to a daily working pressure of 160lb. per square inch, fitted with mechanical stoking plant and fuel economiser. The boiler auxiliaries consist of independent steam-driven feed pumps and feed water filters, coal elevating and conveying plant. The works are electrically driven, current being supplied at 230 volts at the switchboard and distributed to the various motors for driving the screen gear, elevating machinery, auxiliary pumps, lime mixers, and the workshop plant. In addition, power is distributed to the sludge-pumping plant situated at the south end of the precipitation tanks. The sewage treatment machinery embraces rough and fine screens, through which the sewage passes on its way to the catch-pit, a travelling dredger for dealing with the heavy deposit in the catch-pit, revolving lime mixers, and travelling lime mixers for the preparation of milk of lime, and oxidisers for the preparation of iron liquor. A water tank is pro-

[illegible] Crawford, LL.D.; County Councillor Marshall, Mr D. H. Morton, Mr T. B. MacKenzie, of the Clyde Trust; Mr R. M. F. Watson, superintendent Western Division, Caledonian Railway; Mr James G. Moore, Town-Clerk; Mr John Lindsay, Police-Clerk, and Mr Lennox M. Sellar. The croupiers were Bailie P. G. Stewart, Councillors Warden, W. F. Anderson, and John M'Farlane. After luncheon, the loyal toasts were given from the chair and duly pledged.

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The Lord Provost, in accepting the gift, said that it would ever be associated with one of the most momentous events in the history of Glasgow.

Houses of Parliament

Preceptor Mitchell proposed "The Houses of Parliament." He said that the House of Lords was actuated by a desire to do the best for the people of the Empire. The House of Commons was just what we made it. Not only were its deliberations awaited with interest in our own country, but they were also regarded as momentous by the whole of the countries of the world. We looked to the House of Commons to guard our shores from invasion, to make our homes secure, and to make as low as possible the burden of taxation under which we groaned and grumbled occasionally. Above all, however, we looked to the House of Commons to inquire into the conditions of the lives and the homes of the great masses of our people, and to strive by kindly government to make their lives brighter, their homes happier, and their social position more comfortable. Moreover, we looked to the House of Commons to remember that this little island of ours was but the eye of a great Empire, and that far across the sea we had fellow-subjects of our King who were doing their best to promote the grandeur and the advancement of Great Britain, and who had always expected to get sympathy and kindliness and wise and helpful legislation. (Applause.)

Mr Alexander Wylie, M.P., in responding, congratulated the Lord Provost and the members of the Town Council upon the completion of this important section of the great sewage works they had undertaken. (Applause.) It was the greatest work of the kind outside London, and it was worthy of the second city of the Empire, which had always led in municipal matters and in subjects connected with sanitation. It would confer an enormous benefit upon the people of Glasgow, and, next to them, upon the inhabitants of Dumbartonshire. (Applause.) It had been undertaken not for profit, but in the interests of health. One of his principal reasons in coming there was to thank the Lord Provost and the Council, in the name of his constituents, for the great benefit it would confer upon them. From above Yoker, past Clydebank, which was intimately associated with this scheme, Helensburgh, all round the shores of the Gareloch, and up Loch Long, as far as Arrochar, it would conduce to the purity of the Clyde and increase the pleasure of the people. Referring more particularly to the toast, he said his dear old friend, the late Mr John Ure, formerly Lord Provost of Glasgow, and uncle of the present Lord Provost, who had inherited his ability and amiability—(applause)—used to tell him that he preferred the Committees of the House of Lords for genuine business capacity to those even of the House of Commons—(hear, hear)—and no man had a better experience of Parliamentary Committees than Mr John Ure. With regard to the other House, he pointed out that, like Town Councillors, the members did their work entirely without fee or reward. (Applause.)

Presentation to Councillor Anderson.

Mr Greig Robertson, on behalf of the contractors, presented Councillor Robert Anderson, convener of the Sewage Disposal Committee, with a silver rose bowl and a set of four silver flower vases as a souvenir of the occasion.

Councillor Robert Anderson, in accepting the gift, remarked that he regarded it as an evidence of the good relations subsisting between the Sewage Committee and the contractors.

Corporation of Glasgow.

Sheriff Lees proposed "The Corporation of the City of Glasgow."

The Lord Provost acknowledged the toast. He proceeded to remark that the ceremony of that day marked a very notable occasion in the annals of the City of St Mungo. It was to his Lordship a very pleasurable circumstance that many of the colleagues whom he had known in years gone by were with them that day—many who took an arduous share in the work that had led up to the event they were now celebrating. He was delighted that the erstwhile father of the Town Council, Preceptor Dickson—(applause)—proud in the celebration of his eightieth year, but full of energy and abounding in hopefulness for the future of humanity—sat with them, seeing almost the copestone put on a work in which he was earnestly and deeply engaged, and reminding a younger generation that, before their time, thoughtful men had considered problems closely affecting the welfare of the city, and had laid very securely the foundations [illegible] could be [illegible] their [illegible] and he hoped [illegible] all their further advancement would be devoted and consecrated to the service of humanity in the direction of making life healthier, purer, and more enjoyable from the physical point of view. (Applause.)

The Sewage Undertaking.

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Councillor Robert Anderson, in replying, said that in this great scheme they were following the lines laid down by their predecessors. When he joined the Town Council in 1891, if his memory served him, Mr Thomas Mason—(applause)—was the convener of the committee, and he was succeeded by Dr Crawford and Sir David Richmond. They had never seen any reason to depart from the lines laid down. They had experimented with a variety of systems of sewage disposal. While they had proved the excellence of the bacteriological system, they had also proved to their own satisfaction that there was no necessity to adopt it in the case of Glasgow. To have done so would have been a waste of public money, and therefore they had adhered to the well-defined and well-known scheme of chemical precipitation. Anything he had been personally enabled to do had been due to the loyal and confident support of every member of the Sewage Committee, which had also been extended to his predecessors; while they had also as a committee enjoyed the confidence of the Corporation. If they continued to enjoy the same confidence, he had no doubt as to the success of the sewage undertaking. (Applause.)

Neighbouring Local Authorities.

Bailie P. G. Stewart, Glasgow, submitted the toast of "Neighbouring Local Authorities," coupled with the names of Bailie Lang, Partick; Bailie Taylor, Clydebank; and County Councillor Marshall, Renfrewshire.

Bailie Lang, who explained that Provost Kennedy had to leave on important business, said that while they did not at first look upon the sewage scheme as being of much benefit to Partick, he thought he might say that they all recognised now that it would be of considerable benefit. Anything that Partick had to do in connection with the scheme they might depend upon it being done, and if they had to pay an extra rate, as they were doing to the extent of 4d per £1, he believed they would do so with great pleasure so long as it conduced to the purification of the burgh. (Applause.)

Bailie Taylor, Clydebank, said that they were proud to be associated with Glasgow in the scheme. They were very much interested in having the river made wholesome. Under the scheme they expected to improve the health of the community, although they had to pay for it, as they had at present to the extent of 2d per £1 on owners and occupiers.

Mr Marshall, replying on behalf of Renfrew County Council, expressed regret at the death of Mr Mann, one of their ablest members, and one who in this particular matter of sewage purification had a greater grip of the subject than probably any other member. It gave him (Mr Marshall) the greatest possible pleasure to know that there was a prospect in the near future of having a river that was really worthy of the name of the Clyde. When they thought of what it was in the higher reaches, they could only deplore what it was in the lower reaches. He expressed the hope that the very friendly relations which had existed for long between the County Council of Renfrew and the Corporation of Glasgow would continue. He had not the least doubt of that under the present very able management of the city. (Applause.)

Engineers and Contractors.

Councillor Warden, in proposing "Engineers and Contractors," mentioned that by the time these works were completed they would have spent about £1,000,000, which would show that the contracts had been many and the work very varied. Mr M'Donald had been most consistent in his attention to the smaller details, and most insistent in having from the contractors the necessary quality of work. The Corporation were to be congratulated on having an official such as Mr M'Donald, who had not only shown himself efficient and hard-working, but had also, when he thought they were asked to pay more than value, faced the construction of the Clydebank sewer, and, with the able assistance of Mr Easton, had finished the work at considerably less than the lowest offer received by the Corporation. The toast was associated with the names of Mr G. Midgeley Taylor, consulting engineer; Mr A. B. M'Donald, city engineer; Mr D. H. Morton, consulting mechanical en-

[illegible] through the [illegible] two direct-driven [illegible] mos, each capable of delivering 300 e.h.p. and one similar generator, capable of delivering 150 e.h.p. These engines, together with the centrifugal pumping engines, are connected to two independent direct steam-driven surface-condensing plants. The boiler plant consists of four Lancashire boilers, 7 feet 6 inches by 30 feet, suited to a daily working pressure of 160lb. per square inch, fitted with mechanical stoking plant and fuel economiser. The boiler auxiliaries consist of independent steam-driven feed pumps and feed water filters, coal elevating and conveying plant. The works are electrically driven, current being supplied at 230 volts at the switchboard, and distributed to the various motors for driving the screen gear, elevating machinery, auxiliary pumps, lime mixers, and the workshop plant. In addition, power is distributed to the sludge-pumping plant situated at the south end of the precipitation tanks. The sewage treatment machinery embraces rough and fine screens, through which the sewage passes on its way to the catch-pit, a travelling dredger for dealing with the heavy deposit in the catch-pit, revolving lime mixers, and travelling lime mixers for the preparation of milk of lime, and oxidisers for the preparation of iron liquor. A water tank is provided on the roof of the power-house annexe, from which a supply of Corporation or burn water may be drawn. The main sludge tanks are each 150 feet long by 35 feet wide by 10 feet 3 inches total inside depth, built in combination with mid-division common to both. Each tank has a capacity of 1470 tons of undrained sludge, and they are erected on a substructure of brickwork. The sludge is discharged from the precipitation tanks to the pump well under the pump-house, immediately east of the main tank. From this well the sludge is raised by three direct motor-driven centrifugal sludge pumps, each capable of raising 1500 gallons of undrained sludge per minute. These pumps are placed in the pump-house immediately over the pump well, and in this house are also placed the auxiliary motor-driven exhausters and the electrical switchboard. From the tanks the sludge is drawn off through large loading pipes to the wharf, where are placed the sludge loading pipes. These loading pipes have swivelling arms suspended from a gallows on the wharf, and are capable of being lowered out over the deck of the sludge steamer, permitting the sludge to be discharged by gravity from the sludge tanks into the steamer hold. The machinery buildings, treatment machinery, and sludge tanks are to the designs of Messrs D. & A. Home Morton, C.E., 130 Bath Street, Glasgow, and the principal contractors on these works were:—Machinery buildings, Messrs Kinnear, Moodie & Co., Edinburgh; sludge tank buildings, Messrs Robert M'Alpine & Son; treatment machinery, Messrs D. Stewart & Co. (1902), Limited; and sludge tank, Messrs A. F. Craig & Co., Paisley.

opinion would, unquestionably, be in favour of the separate system, since, instead of requiring to construct outfall sewers to take in storm water, with all the concomitant requirements of storm valves and bye-passes, and to make provision for the treatment of the excess of storm water up to six times the dry-weather flow, as the combined system demands, the engineer can construct channels of such appropriate size and shape as are necessary to deal with a fairly constant flow, and at much less initial cost. Further, purification in the combined system, by reason of the variability in amount of storm water, is inconstant and uneven, and at times illusionary, whereas in the separate system there is a comparatively constant and even flow of sewage to deal with, the purification of which could therefore be more complete. But where a huge combined sewage system has been gradually evolved, the enormous cost requisite for conversion of the combined system into a separate system is a fatal bar to the introduction of the separate system. The sewage of a populous place is constituted of the products from three distinct sources, viz.:—

1. Domestic Sewage, consisting of excretal matters and waste-water, which is composed chiefly of nitrogenous and carbon compounds;
2. Manufacturers' Discharges, comprehending the waste fluids from divers trade processes, which is made up of the most varied chemical compounds; and
3. Municipal sewage, in which may be included waste-water and other fluids from stables, cow-byres, cleansing of streets, courtyards, and public conveniences.

The respective amounts of these in different sewages varies, but on the whole there is general similarity in the composition of those of populous places. It is especially with respect to smaller towns which are identified with certain particular industries, and in which, therefore, the ratios between domestic sewage and trade effluents are abnormal, that the question of composition of sewage has significance with reference to special modes of purification; for example, where the discharges of pot ale from breweries equal in amount or form a large proportion of the domestic sewage.

Modes of Sewage Purification may be divided into two classes, viz.:—

I. Natural.
II. Artificial.

Under the former may be included *Surface or Broad Irrigation*, which under special supervised conditions has been termed *Sewage Farming*. Under the latter are comprehended: (*a*) *Precipitation* or *the Chemical Method*; (*b*) *Intermittent Downward Filtration*; (*c*) *Bacteriolysis*, or the *Biological* or *Bacteriological Method*.

Such a classification as above is merely a working one, and does not pretend to be scientific, since in none of the so-called Natural methods is there absent some measure of artifice, while in most of the Artificial methods natural processes and agencies are important factors.

There are two tests by which the efficiency of any method of purification may be tried: (1) Its intrinsic worth when in operation under the most favourable conditions; (2) its applicability to the circumstances of any given place.

I. *Surface or Broad Irrigation.*—In this method, the sewage is conveyed to a convenient sloping piece of land, upon the surface of which, by means of channels in which its flow can be diverted where wanted, the sewage is passed. The water which percolates through the soil ultimately finds its way into natural water-ways, just as does the rain. If the soil be sandy or gravelly, percolation is rapid, provided the surface does not become clogged by too long continuous flow over the same area. The land, so enriched, is used for the abundant growth of certain crops, as Italian rye-grass, etc. Clayey or dense soils are unfitted for the purpose. The method is in operation in many small towns. When viewed from all points, the system cannot be deemed successful or efficient. It is apt to fail in times of severe rainfall and frost, and the area of irrigation is liable in warm weather to become objectionably odorous. Reasonable success, however, may be achieved by close supervision. From the point of view of applicability, it can but best serve small rural towns, and is rarely applicable to large populous centres, because of the enormous tract of land required. In Birmingham, for example, where this system is in operation, the sewage-farm of 1240 acres originally in use has had to be increased in area to 2432 acres, or nearly double its initial size. In Berlin, 20,000 acres of land were purchased for this purpose. The results of the system as carried out in the latter city, from the point of view of profit and loss, cannot be compared with those of other places, because the labour is provided chiefly by persons condemned for minor misdemeanours, and therefore costs nothing except for the maintenance of those employed. The system, although still in use in Edinburgh, has out-grown its suitability.

Sewage Farms fail in their purpose without the closest supervision. With such supervision, however, and suitable land, they may be worked to a high pitch of efficiency. For example, the sewage of Wrexham, with a population of 12,000, is treated on 150 acres of good land. As the effluent from this farm runs into the river Dee above the in-take of the Chester Water Company, it is imperative that the effluent should be satisfactory.

II. *Intermittent Downward Filtration.*—The essential factors of this system are: (1) Land suitable in kind and in area; (2) preparation of land into a series of plots in the form of large filter-beds; (3) a convenient water-way into which to run the effluent. The intrinsic merits of the system are high. The prime cost of installation is very considerable. Not only must the outfall sewers be extended to the site chosen, and tanks and channels be erected there, but the site itself must be specially prepared for operation. The land must be excavated to a depth of six feet, the bottom laid with agricultural tile-pipes at regular intervals, and on top of these from below upwards, successive layers of small boulders, gravel, and the natural soil if porous, or, if not, imported sandy soil. These plots, so prepared, are simply huge filter-beds, through which free percolation of fluids not only takes place, but by the action of nitroso- and nitro-bacteria, complex albuminous substances are split up into elementary gases, and nitrites and nitrates are formed. From a tank at the works the sewage during dry weather flow can be run by gravitation to the plots in series, or where the

levels do not allow of this, and during storm flow, auxiliary pumping from a storage tank must be employed. The sewage is distributed by channels to a given plot or plots working in series, and in such rotation that each plot or series works for six and rests for eighteen hours, so as to allow of complete re-aëration of the soil. The percolated fluid which constitutes the effluent finds its way by an artificially prepared channel into an adjacent water-way; the solids are incorporated into the soil by ordinary agricultural operations, and thus a soil is made rich for the growth of crops, such as hay, cabbages, turnips, osiers, etc. The applicability of this method is affected by three main factors: (1) its relatively high prime cost; (2) the extent of land needed for a large population; (3) the difficulty of procuring convenient and suitable land. The filtering area of ground required under the best conditions is 1 acre per 1000 of population, and under less favourable, 1 acre per 150 to 500 of population. The extent of land necessary, therefore, for huge populations, coupled with the high prime cost of its preparation and the cost of maintenance, tend to make the scheme inapplicable for other than small town populations. At the same time the cost of working and maintenance is much less than that of other schemes, and when properly managed, the land can be made to yield some return in the crops produced.

III. *Precipitation Methods* or *Chemical Treatment.*—Of the very many substances which have been proposed as chemical precipitants of the organic and inorganic matters in sewage, few have survived the tests of time, cost, and efficiency. Those which have survived these crucial tests are: (*a*) Lime, (*b*) Alumina, (*c*) Magnesia, and (*d*) Iron; used not singly but in some form of combination. Lime is the oldest precipitant in point of time of use, but unless it is used in sufficient quantity, it fails to precipitate effectually organic matters. When used in such quantities it produces two objectionable results, viz.: (1) an alkaline effluent which becomes subject to secondary decomposition, causing the effluent to be richer in putrescible matter than the original sewage, and hence causing the stream into which the effluent is passed to become a definite nuisance; and (2) a bulky, decomposable sludge. The treatment by lime was then united with filtration of the effluent; but this also proved inefficient, since the finely-divided, putrescible, slimy material in the effluent rapidly clogged the filters. By reason, therefore, of its needed use in comparatively large amounts, its alkaline, putrescible effluent, and the bulk of sludge produced, the use of caustic lime solely, or combined with filtration, came to an end. Next followed the conjoined use of coarse sulphate of alumina with lime. This produced two marked results, viz.: reduction in the amount of lime needed, and a more perfect and more rapid sedimentation of solids. To these might be added a third: a more neutral condition of effluent, and hence less liability to secondary decomposition. The chemical action of alumina on sewage is somewhat akin to that of iron, inasmuch as it tends to split up complex and stable albuminoid bodies into less stable and complex nitrogenous compounds in the direction towards the formation of ammonia, but unlike iron, it does not possess the property of oxidis-

ing carbonaceous compounds. When alumina and lime are used together, the sulphuric acid of the former unites with the lime and leaves the alumina in the form of hydrate, $Al_2(OH)_6$, which, being a gelatinous, viscid substance, more readily carries down mechanically particulate matters in suspension. The property which alumina has of fixing nitrogenous matter by entering into some form of loose combination with it, would appear to be analogous to the action of a mordant in dyeing processes. Relatively to iron, alumina has less power of fixing phosphoric acid and ammonia, and like lime, it contributes of itself no manurial value to the sludge. The combined use of these precipitants with filtration of effluent has been demonstrated at Coventry, Glasgow, and other places to produce a good effluent; but both are essential to achieve this.

As an offshoot of the Lime-alumina process is the *A.B.C.* process, which has been in operation in Aylesbury, New Kingston, and other places for several years. The precipitants are alumina, blood, clay, and charcoal—hence the name of the process from the initial letters of these substances. The mode of treatment is as follows: On entering the works, the sewage is screened, measured, and mixed with regulated proportions of the three last-named chemicals, and then, later, with the alumina sulphate. Thus mixed, the sewage is passed into four precipitating tanks, in which rapid sedimentation of solids takes place. Out of the fourth tank of the series flows the effluent which is passed into the water-way. The precipitated sludge is then pumped to a sludge well, whence it is forced into filter-presses. The cake so formed is thereafter dried in a Borwick's drying cylinder, the fumes therefrom being condensed by a scrubber. The product is sold as "native" guano. It is claimed for this process that not only is the sewage efficiently purified, which is the prime object, but also that the sludge forms a comparatively valuable, innocuous, transportable, and inodorous manure. Whatever manurial importance this product possesses, however, must be held to be due to the added ingredients, and not to those native to it. Another precipitant of importance, in one form or another, is iron. So far back as 1846 and 1858 patents were taken for the use of iron in the treatment of sewage; that of 1858, by Thomas Spencer, a London analytical chemist, was for "Improvements in the treatment of iron ores and ferruginous sands, and certain applications arising therefrom, No. 1415." When iron is mixed with sewage one of the most noteworthy changes which takes place, detectable in the effluent, is the substantial increase in the amount of free ammonia and decrease of albuminoid ammonia as compared with those respectively in raw sewage. The action of ferric chloride upon carbonaceous and nitrogenous bodies in sewage is to liberate carbon from the former to be oxidised into CO_2, and nitrogen from the latter, which uniting with free hydrogen, forms NH_3; in this way accounting for the increase of free ammonia found. It would appear that the water bound up in the hydrated oxide of iron does not exist as true water—which is very stable—but as *hydroxyl* which is very unstable, and that iron salts therefore play a part analogous to the action of permanganate of potash in the Wanklyn process for conversion of albuminoid bodies into ammonia. The action

of liberating the carbon may be represented by the following equation :—

$$3\ Fe_2(OH)_6 + 3C = 6Fe(OH)_2 + 3CO_2 + \cancel{H_6},$$

in which the hydrated ferric oxide becomes reduced to the ferrous condition in oxidising the carbon, the carbon to be oxidised to CO_2, and nascent hydrogen to be set free. The hydrogen then unites with the freed nitrogen to form NH_3; thus :—

$$6Fe(OH_2) + \cancel{H_6} + N_2 + 3H_2O + \cancel{O_3} = 3Fe_2(OH)_6 + 2NH_3;$$

in the meanwhile, the ferrous oxide takes up fresh oxygen from the air and reverts to the ferric state.

When iron is used as a precipitant, efficient filtration is imperative to permit of re-oxidation of the ferrous oxide.

Iron may be added to sewage in a variety of forms, as for example :—

1. A solution of Ferric Chloride;
2. A solution of Sulphate of Iron; as in the *International*, *Polarite*, or *Ferrozone* process;
3. A solution of Iron-Alum;
4. A combination of Ferric Chloride and Lime; as in the Barry process;
5. The electrical process, in which iron is set free by the electrolysis of water.

The first is used as any other precipitating agent, and needs no further explanation. The second consists in adding to the crude sewage a solution of ferrous sulphate of regulated strength, popularly called "ferrozone," and in filtering the effluent through beds composed of oxide of iron—called Polarite by some, and Magnetite by others—a ferroso-ferric oxide, or magnetic oxide of iron. The third consists in adding a solution of crude iron-alum, as is done at Southampton. The Barry process uses both ferric chloride and lime, the latter assisting in the more perfect sedimentation of the iron as ferrous hydrate, and thus less work is thrown upon the filter-beds. The sewage is first mixed with the iron, and thereafter with the caustic lime. Adequate filtration is absolutely needful in this process, since the utility of the iron for repeated use is only conserved when the iron is oxidised back to the ferric state, and this is achieved by re-aëration of the filter-beds during their intervals of rest. The electrical process is one in which iron is shed by the action of electricity into the passing current of sewage in the following manner: The sewage is passed at a low velocity through a chamber which is broken up into part sections by the projection into its interior of iron plates forming flanges. These iron flanges are in the electric circuit, and when the current is in action through the apparatus, one set becomes the negative, and the other, the positive poles. From the latter only, hydrated ferrous oxide is produced by the action of the oxygen liberated from electrolysis of the water by the electric current upon the iron plates. This ferrous oxide is oxidised by the dissolved oxygen in the sewage into ferric oxide which oxidises the organic matter, by which it is converted back into the ferrous state; and so by alternate oxidation and de-oxidation, the iron continues to act upon the organic constituents

λ 3 H 2

λ 3 H 2 30

of the sewage. The sewage, mixed with the iron in suspension, then passes from the electrolysing chamber into settling tanks, and, thereafter, the effluent is passed through ordinary sand filter-beds. There is another modification of the alum-iron process worthy of description. It is the process carried out at Heaton Mersey for purifying the sewage of the Heaton Norris Local Board District. The points of interest in it are these: (1) It is a constant-flow system; (2) The precipitant in use is alum cake which is added prior to the sewage passing by gravitation into the precipitation tanks; (3) After precipitation, the effluent flows over a sill forming a cascade about one foot in height, on its way to the filter-beds, thus promoting aëration of the oxidisable constituents in the effluent; (4) The filter-beds are three in number, and the composition of each is different. No. I. has an area of 60 yards; and the filter-strata, from above downwards, are made up of sand, coarse and fine gravel, of one inch and six inches thickness respectively, both of which strata rest on tiles which are perforated with five openings to the inch. Aëration of the filter when not working is effected by pipes. This filter, therefore, acts only as a mechanical coarse strainer. No. II. filter-bed is made up of a layer of magnetite and sand mixed, of 2½ inches depth, resting upon gravel. It has an area of 35 yards. No. III. is constituted from above downwards of the following layers, viz.: sand 1 inch, magnetite 7 inches, and pebbles and tiles as above. It has the same area as No. II. The effluent after its passage through these has a bright, clear appearance, contains no matter in suspension, and possesses no smell. It is claimed for the process that it combines rapidity of filtration and a decreased filter-area, with the production of a pure, innocuous effluent, at half the cost of any filtration system in operation. In these works, the sewage, which contains no trade-effluents, is that of 6000 persons, and amounts to 240,000 gallons per 24 hours. Of iron, generally, in sewage treatment, it may be said that it produces more marked fixation of the phosphates than does either lime or alumina singly, or in combination.

The only other precipitant which has borne the tests before named is Magnesium chloride. This is the main constituent of the chemical salts used in Hillé's process, which is in operation at Windsor, Tottenham, and other places. This process is a modification of the lime process, because lime and a proportion of tar are also added. The effluent is subjected to what filtration irrigation can give. Another modification of the alumina process is that of the Oxygen Sewage Purification Company, in which, however, Manganate of Soda and Nitrate of Soda are additionally used. This process may be summed up as follows: (1) Suspended matters in the crude sewage are first separated by simple subsidence; (2) Manganate of Soda is added, to oxidise organic matter, that salt giving up oxygen, and becoming reduced to the insoluble peroxide of manganese, which in its subsidence carries down mechanically the particulate sewage, the manganese being afterwards recovered; (3) Sulphate or Chloride of Alumina, preferably the latter, is next added, which throws down the floating, flocculent matter left from the former stage; (4) To the clear resulting effluent small quantities of Nitrate of Soda, to aid

nitrification, are added; (5) Thereafter, the effluent is turned into the nearest stream. In this process there are three sediments; (1) the crude solids deposited by gravity; (2) the deposit from use of Manganate of Soda; (3) the deposit from the alum salt; thus mechanical subsidence, chemical precipitation, and oxidation all share in the production of the result.

The outstanding objections to all precipitation methods are the formation of sludge, and the need for its removal. Burghardt's analysis of the fresh sewage sludge from the lime process is as follows:—

Mineral matter	6·22 per cent.
Loss on ignition of dry sludge (organic matter)	2·50 ,,
Water	91·28 ,,
	100·00

Composition of the above mineral matter in parts per cent. is as follows:—

Silica and insoluble matter	10·418
Ferric oxide and alumina	9·511
Iron sulphide	0·115
Calcium carbonate	64·526
,, sulphate	3·621
Magnesium carbonate	11·613
	99·804

Our analyses of the sludge at the Glasgow works after having been filter-pressed, show the following to be the composition of an average sample:—

Total solid residue		41·50
Mineral matter	= 24·38	
Organic matter (by ignition)	= 17·12	
	41·50	
Water		58·50
		100·00
Total nitrogen (estimated by Kjeldahl's method)		= 0·788
Total nitrogen in terms of ammonia		= 0·960

By reason of the comparatively low manurial value of the foregoing, and the difficulty experienced in its disposal, the authorities at Glasgow concluded to dry the compressed cake artificially, thereby getting rid of about 90 per cent. of water. The following analyses of this compressed and steam-dried cake, ground into powder, show its composition in parts per cent.:—

		Davidson.		Glaister.
Total solids		89·37		93·00
Mineral matter	49·70		66·5	
Organic ,,	39·67		26·5	
Water		10·63		7·00
		100·00		100·00
Nitrogen		1·73		1·90
,, in terms of ammonia		2·10		2·30

It will be apparent from the foregoing analyses, therefore, that the sludge from precipitation processes, even when compressed and dried, forms a manure of comparatively low value only. Further, the low figures for phosphoric acid indicate that the bulk of this valuable manurial element has disappeared with the effluent into the river. If the sludge could be disposed of for agricultural operations, precipitation processes would become more workable and less costly.

The following Table will show the amounts of sludge produced by different methods of treatment.

TABLE XVI.

Results *per annum*, in tons of wet, pressed, and dried sludge, of Treated and Non-treated Sewage, per 10,000,000 gallons of *daily* average sewage by various Precipitants.

Character of Sewage.	Tons of Wet Sludge.	Tons of Pressed Sludge.	Tons of Dried Sludge.
Raw Sewage (untreated) .	58,000	11,680	5,840
Lime, only	114,200	22,840	11,420
Ferric Chloride, only . . .	120,000	24,000	12,000
Iron and Alumina . .	120,000	24,000	12,000
Polarite Method . . .	75,000	15,000	7,500
Electrical Method . .	69,000	13,800	6,900

The foregoing figures are founded on the results obtained in the Salford experiments of 1890 by the Messrs. Newton, and they are intended to show the amount of sludge which is formed from 3,650,000,000 gallons of sewage, after different precipitants had been used. At the Glasgow works during the year 1897–98, the number of gallons treated was, in round numbers, 3,740,000,000, a figure sufficiently near the former for comparison. The quantity of wet sludge taken from that quantity of Glasgow sewage was 180,000 tons; and of pressed sludge, 17,000 tons. From these figures, it will be seen that the amounts obtained in the latter are higher than the highest figure of the Salford experiments.

In the Act of Parliament obtained by Glasgow for extending this mode of purification to the whole sewage of the city, powers have been given to the Corporation to transport the sludge out to sea, and to deposit it therein. When the completed scheme is in operation, since the estimated amount of sewage to be treated will not be less than five times more than now treated at Dalmarnock (based on the figures given of the results of the partial scheme), it appears that annually, the city will have to deal with between 950,000 and 1,000,000 tons of crude or wet sludge, and to dispose of, in one way or another, between 90,000 and 100,000 tons of pressed sludge-cake, as the result of operating upon about 20 billion gallons of sewage.

In all schemes of precipitation, filtration is a necessary adjunct before the effluent can be passed without nuisance into a water-way. While, therefore, precipitation processes are applicable to large populous centres, and are capable when worked properly of effecting a high degree of purification, they are very costly not only in installation but also in maintenance and working.

IV. *Bacteriolysis*, or *the Biological* or *Bacteriological Treatment.*

From time to time during the last half century, since drains for the transportation of sewage came into more general use, when these or cesspools, which for long periods had been so used, were opened, and were expected to contain quantities of highly offensive material, surprise was expressed on finding them comparatively empty and entirely free from objectionable, offensive odours. But the reasons therefor were passed over without further inquiry, doubtless due to the fact that the effects of micro-organisms in the destructive metamorphosis of organic matter were not even dreamt of, much less understood or investigated.

The first publication which indicated the probable action of micro-organisms as the natural cause of purification of sewage, was a pamphlet entitled "A New, Hermetically Closed, Completely Inodorous, Incessantly Self-Emptying Cesspool, invented by M. Louis Mouras, proprietaire, Vesoul (Haute Sâone)." This pamphlet was written by a parish priest named Abbé Moigno, and was published in French about the year 1883. The substance of its facts is the following: In 1881, M. Mouras asked the Abbé to publish his observations of a cesspool system which the former had had in operation for about twenty years previously. The features of the cesspool are fully named in the title of the pamphlet. It was closed from the air; its products were inodorous; and they were found valuable as a liquid dressing for cultivated land. According to the Abbé, "by a mysterious action which reveals an entirely new principle, the cesspool transforms all that it receives, both solid and liquid evacuations, in a tolerably short time, and without any addition of chemical ingredients, into a homogeneous and scarcely turbid liquid, which holds everything in suspension in a state of filaments almost invisible without leaving any deposit against the sides of the soil-pipe, or at the bottom of the drain-pipe." Not satisfied only with noting these results, the Abbé discusses the rationale of the causal factors in the process. He hints that the cause may be ammonium sulphide, but he adds this significant remark: "May it not be discovered that the mysterious agents of this fermentation, cause of the decomposition and liquefaction of the fæces, are the vibrios, or rather the anaërobes of M. Pasteur, which the oxygen kills, and which only employ their devouring activity when excluded from the air." He set about experimenting on the subject, and had a tank of glass made, so that he might study the whole process of metamorphosis. He then describes the changes which he saw the sewage undergo toward complete disintegration. He thought it likely that gases would be generated by the processes of fermentative decomposition, and to test this, he caused a tap to be fixed in the top of the tank, over which he placed a bladder securely fastened. He found, however, that no distension of the bladder occurred, indicating that in the absence of air there was no free disengagement of gases, and that they were held in solution, but if air was admitted into the tank the gases were liberated and the bladder became distended. He thereupon concluded that, for the more efficient operation of the process, air should be rigidly excluded from the tank. He further believed that by the process any pathogenic organisms which might be present in the sewage would be destroyed. The process was patented in France in 1881. The next account, in point of priority, comes from Barcelona.[1] The British Consul in Barcelona wrote a letter in 1893, in which he narrated the operation of the above system on the property of a merchant in that place in the drainage of his factory and private residence. The Consul states that he had personally inspected the process and its results after five years' working. He found the effluent colourless and odourless, and that it could be removed for manurial purposes without the least nuisance. The next attempt to prove the efficacy of bacterial action in purifying sewage was that of Dibdin, who, between 1892–96, carried out a series of experimental inves-

[1] Boyce, *Brit. Med. Jour.*, 1898, vol. ii. p. 273.

tigations in open beds, under the auspices of the London County Council, on the biological treatment of sewage.

By Cameron of Exeter, in 1895–96, an experimental installation was laid down in that city to deal with the sewage of the parish of St. Leonard. The principles which Cameron adopted were practically those laid down by Abbé Moigno, but Cameron called his tank the "Septic tank," in place of the long name given to it by Moigno. Since, however, the effluent of the septic tank at Exeter was not employed in the irrigation of land, but was to be discharged into a stream, he passed it through beds, which, while they exercise filtering action, also develop microbic action, from which the names "filter beds," "bacteria beds," and "contact beds" have been given to them.

Rationale of the System.—The Bacterial treatment of sewage has now been practically resolved into one of three methods, viz.:—

1. Where the crude sewage is run upon filter or contact or cultivation beds, composed of coke or other materials, the rate of flow of sewage being regulated, and the contact beds themselves subjected to alternate periods of active work and complete rest;

2. Where the crude sewage is first run into a grit chamber, then into a closed, dark tank, called the septic tank, and, thereafter, is passed on to contact beds,—all the time in a slow but continuous flow,—in which it is allowed to remain in contact for $1\frac{1}{2}$ to 3 hours, after which the effluent is passed into a neighbouring water-way;

3. Where the sewage is passed into an open settling tank, thence to the contact beds, and in turn to the stream.

The first may be fitly termed the *ærobic* method; the second, the combined *anærobic* and *ærobic* method; and the third, the same as the second; for although there may be apparent differences in the engineering technique in the third compared with the second, the intimate action is essentially identical. These apparent differences may now be described. In the open settling tank of the third method, a thick, frothy, tough scum gradually forms upon the surface of the contained sewage, provided that the rate of flow is properly regulated, which scum, to all practical intents and purposes, plays the part of the roof of the septic tank, inasmuch as it prevents the entrance of light, and to some extent of air to the sewage column underneath, and so the action of anærobic organisms is allowed to proceed. The integrity of the scum-covering is liable upon occasion to be disturbed and broken up by the action of high wind, but only, however, for short periods. When this mode is adopted the tank ought to be sheltered by a protecting wall.

Nothing has been better proved in the whole range of bacteriological work than the power of organisms to split up complex organic bodies into simpler constituents, as nitrogen, sulphur, carbon, hydrogen, and others, and that different groups of organisms are synthetic in their action in respect that they are able to oxidise nitrogen from the lowest to the highest state. In the metamorphosis of the complex fluid—sewage—each group of organisms has a definite part to play. The anærobic forms are chiefly concerned with the resolvant or analytic decomposition of contained substances, and the elements liberated unite with one another to form definite gases or other compounds which are retained in solution; thus sulphur unites with hydrogen, or with that gas and nitrogen in addition, to form

H_2S and NH_4HS respectively, while nitrogen unites with hydrogen to form NH_3, which, in turn, may unite with acids, as H_2SO_4, HCl, or CO_2 to form the sulphate, chloride, or carbonate respectively. The foregoing action is accomplished in the dark, airless tank. When however the sewage so acted upon passes in its slow moving course out of the tank and over the artificial weir, it becomes partly re-oxygenated by the air, and absorbs in addition the other atmospheric gases, nitrogen and carbonic acid; and thus, freshly aërated, it is passed on to the surface of the contact beds. In these contact beds, the anærobic organisms continue their operations during the time the beds are full, and the ærobic organisms take up the work while the beds are empty and resting. Two kinds of action take place in these beds, viz., (*a*) the mechanical one of straining or filtration; (*b*) the biological, or bacteriological. The former depends upon the coarseness or fineness of the constituents of the contact bed, but it is not the most important office of the bed. The period in the life of a contact bed at which it does the most efficient work is not when it has been newly laid, but after it has been in operation at intermittent intervals for at least two or three weeks; in short, so soon as the ærobic organisms have had time to adequately grow and multiply. Hence the work of the contact bed is not so much that of filtering the effluent, as of assisting microbic action. The work of the ærobic organisms is mainly synthetic or constructive. They are chiefly, for sewage purposes, divisible into two groups, viz. :—

1. The Nitroso-bacteria; and
2. The Nitro-bacteria;

each of which exercises a limited, but definite action upon the above-named products. The former group attacks the ammonia and its compounds, and oxidises the nitrogen liberated into the form of nitrous acid, which forms with constituent bases of the sewage—potash, soda. etc.—nitrites of these bodies. Nitrous Acid (HNO_2), however, is a comparatively unstable compound. The nitro-bacteria then build up further the oxidation process by causing the nitrous acid to unite with another atom of oxygen, thus forming *nitric* acid (HNO_3), the highest and most stable form of oxidised nitrogen. The range of the action of nitrification is only limited by the amount of calcium present in the contact bed, or in the soil. These actions and results have been abundantly proved by the researches of Warington, Lawes and Gilbert, Frankland, and many others. The nitric acid unites with the bases, potash, soda, and ammonia, to form nitrates, immense beds of which are found in nature in South America and other parts of the world, and which form important constituents of artificial manures. As the combined effect, therefore, of filtration and bacterial action, the effluent passes from the contact beds, as a clear, inodorous, and practically tasteless fluid.

The Ærobic Process.—In this process there is no closed septic tank as such. The sewage, after having been screened of any coarse excreta, is run intermittently over open filter or contact beds until the sewage is on a level with the top layer of the filter-bed. It is allowed to remain in contact with the material of the bed for two or three hours—that is, 1½ hours in filling, and the same time standing full—and is, thereafter, allowed to drain through. The bed after being emptied, is allowed to rest for eight hours to permit of re-aëration, when it is

again filled and the process repeated. Experience has shown that a period of four weeks is necessary before such a bed attains its fullest purifying power; in other words, the maximum growth of nitrifying organisms is then reached. In certain installations, however, the effluent from the primary or coarse-contact bed is caused to pass through a secondary or fine-contact bed. The effect is to produce a much purer and clearer effluent. The work which falls upon it to perform is that of oxidising the dissolved organic matter in the fluid, the suspended matter being mainly arrested in the coarse-contact bed.

In the Anærobic-Ærobic, or Septic Tank Process, the sewage passes through a grit chamber, where heavy mineral detritus subsides, then through the septic tank, then over the artificial weir for re-aëration of the fluid, and thence on to the contact beds, from which by the effluent channel it passes into a water-way. There is no screening of coarse excreta from the sewage in this process as there is in the other, consequently more work falls to be done by the anærobic organisms. In order to produce that automatic distribution of the sewage after it has passed through the septic tank and has been re-aërated, various ingenious arrangements have been devised. In Cameron's process automatic alternating gear is an essential feature, in which the various stages of filling, resting full, discharge, and aëration are produced by means of an overflow from the filter last filled. In Adam's process, it consists in emptying the tank down to a certain level by siphon action.

While microbic action is the chief factor in the bacteriological process, it must however be borne in mind that in the processes of irrigation, intermittent downward filtration, or indeed in any method in which the sewage or its effluent is applied to land or filter beds, it plays a not unimportant part. Neither is the action awanting in the precipitation process; but in it the action is probably more anærobic in character than ærobic, not only in the sewage itself, but particularly in the alkaline sludge.

In connection with the bacterial treatment, it has been asked, Is it applicable to all kinds of sewage? Microbes do not live and multiply so freely in acid media as in alkaline. There are several trade effluents which are highly acid in reaction, and, therefore, where these bulk largely in the sewage of a particular place, the applicability of the bacterial system becomes an important question. The answer must be based upon the relative proportion of trade effluents to ordinary domestic sewage. In most cases the latter is sufficiently in excess to neutralise the acidity of the former, and hence up till now in practice no sewage has been found which is not capable of being purified by the system. Pot ale or burnt ale, which is the residue from the first distillation of whisky, is probably the most refractory constituent. It contains between 30 and 40 grains of free or saline, and between 40 and 60 grains of albuminoid ammonia per gallon, yet this is overcome by the ærobic bacterial method, as the effluents, which are clear, without colour and odour, and do not undergo secondary decomposition, show infinitesimal amounts of free, and only 0·1 grain of albuminoid ammonia per gallon, while the nitrates are as low as 0·2 grain per gallon. These results, moreover, seem to be obtained whether the pot ale is treated in its natural acid state, or after the addition of a small proportion of lime. Further, from the experiments at Yeovil, the sewage of which is alleged to be exceptionally foul by reason of the trade effluents from glove-works, dye-works, tanneries, fell-mongering works, and breweries, it is demonstrably clear that the process is effective, as the following series of analyses by Dr. Rideal show.

Table XVII.

Analyses of Samples of Sewage from Yeovil in parts per 100,000.

Number.	Date and Time.	Total Solids.	Oxygen consumed.	Chlorine.	Nitrogen. Free or Saline.	Nitrogen. Albuminoid.	Nitrogen. Nitrite.	Nitrogen. Nitrate.
Series I.								
Raw Sewage	Nov. 14, 1899, 8 A.M.-NOON	134	11·22	11·8	4·85	1·64	Nil	Nil
Tank 4	Nov. 15, 1899, 8 A.M.	90	5·2	10·0	3·45	0·57	Nil	Nil
Filter 5	,, ,, 1.15 P.M., No. 2 Filter	78·5	2·22	10·0	1·64	0·29	0·044	0·412
,, 6	,, ,, 2.45 P.M., No. 7 ,,	80·5	1·72	10·2	1·23	0·21	0·015	0·60
,, 7	,, ,, ,, No. 8 ,,	80·7	1·48	9·8	0·99	0·16	0·030	0·712
Average Filter		79·7	1·81	10·0	1·29	0·22	0·030	0·575
Series II.								
Raw Sewage	Nov. 14, 1899, 4-8 P.M.	147	8·8	22·0	3·0	1·03	Trace	Nil
Tank 9	Nov. 15, 1899, 4-8 P.M.	123·5	7·04	17·3	4·08	0·82	Nil	Nil
Filter 10	,, ,, 9.25 P.M., No. 2 Filter	87·5	2·22	14·4	1·64	0·32	0·12	0·12
,, 11	,, ,, 10.55 P.M., No. 7 ,,	90·0	2·64	13·3	1·22	0·30	0·037	0·188
,, 12	,, ,, ,, No. 8 ,,	88·0	0·53	12·6	0·82	0·19	0·024	0·576
Average Filter		88·5	1·80	13·4	1·23	0·27	0·060	0·295
Series III.								
Raw Sewage	Nov. 15, 1899, Midnight-4 A.M.	59·0	2·1	4·8	1·22	0·30	0·018	Nil
Tank 13	Nov. 16, 1899, ,, ,,	124·0	6·08	15·2	4·08	0·72	Nil	Nil
Filter 14	,, ,, 6.30 A.M., No. 3 Filter	85·5	2·55	14·6	2·46	0·26	0·050	0·12
,, 15	,, ,, 8 A.M., No. 7 ,,	90·0	1·81	14·0	1·48	0·21	0·032	0·26
,, 16	,, ,, 8 A.M., No. 8 ,,	87·5	1·07	14·0	1·20	0·20	0·027	0·46
Average Filter		87·7	1·81	14·2	1·71	0·22	0·036	0·28

Percentage Purification.	Organic Nitrogen.	Oxygen Consumed.
Tank on Raw Sewage	64·81	17·09
Filtrate on Raw Sewage, First Filtrate .	85·55	68·38
" " Second " .	87·0	79·10

If the chemical side of bacterial treatment be considered, the fact appears that from the time the sewage enters the septic tank, or open tank, till it appears as effluent, there is a loss in the total nitrogen; in other words, the nitrogen of the effluent falls short of that of the crude sewage. This has been noted by many observers. The results obtained at Sutton, Leeds, Manchester, and elsewhere show this; in these places the percentage of loss was 15, 7, and 39 per cent. respectively. This loss of nitrogen is accounted for in two ways, viz.: (*a*) by the escape of free nitrogen from the sewage by the action of organisms of the anærobic type, or (*b*) by the utilisation of nitrogenous compounds as foods by small insects and other animals, as worms, etc., in the filter-beds. There is another explanation, however, and that is, that there may be nitrifying and reducing organisms working together, the former building up from ammonia the oxidised nitrogen compounds, and the latter reducing such compounds when formed, for it is quite clear that ærobic organisms are not alone present in the contact beds.

Materials of Contact Beds or Filters.—The contact beds are either made by constructing artificial walls, or by simply excavating the ground, where such is of clay; in either case, loose-jointed tile drain-pipes are laid along the bottom, and these lead to the outlet by which the effluent passes. Upon these pipes is placed the filtering or contact material, which may consist of broken clinker, burnt ashes, coke, or pan-breeze, the last-named being used at Barking. In the first or coarse-contact bed the material is composed of sizes which will pass through a two-inch ring, but not through a half-inch ring. In the second or fine-contact bed, such sizes as will pass through a quarter-inch but will not pass through a one-sixteenth-inch sieve are put down. It has been found experimentally that when the material is so composed, the filter-beds do not become so easily clogged, aëration is most efficient, and the effluents are better. The depth of the beds varies. At Barking the depth is 6 feet, at Sutton 3 feet 6 inches, and at the Crossness experimental installation it is 13 feet. It might be expected that these beds after prolonged use would become malodorous; but such has not been found to be produced. Indeed but for the slime which forms in the upper few inches of the bed, the whole bed, and lower layers especially, are fresh after years of working. This is the result of re-aëration. In the experimental stages of sewage-treatment by contact beds, it was thought sufficient that single coarse-contact beds should be installed. But it was found experimentally that such were insufficient, since precipitated solids were apt to be discharged along with the effluent. The only conditions in which such primary beds are found sufficient are where the sewage is applied in drops, by means of mechanical sprinklers, and where the outflow at

outlet is slow and continuous. In present-day installations, therefore, both primary and secondary contact beds are put down, the materials of which are of the composition and size hereinafter described. The effect of such primary and secondary contact is not only to secure more efficient bacterial action, but to produce better effluents. In occasional instances, however, attempt is made to secure the same effect by one bed only,—by the bed being composed of strata of different degrees of size of filtering or contact material. At Barrhead, near Glasgow, for example, the total depth of the beds is four feet, the lower three feet nine inches of which are made up of engine ashes screened through a ¾-inch screen and rejected by a ¼-inch screen. The upper three inches is composed of finer material than the lower stratum. But modifications in the composition of these filter-beds have from time to time been proposed. In Stoddart's sewage filter, which has no built retaining walls, the filtering material consists of coarse rubble, ballast, coke, or other material, varying in sizes between two and four inches, and laid to a depth of six feet. The whole bed is laid upon a concrete floor, with a fall toward one end. The sewage is applied, not *en masse*, but in a continuous stream of drops, by means of distributors which consist of corrugated iron of alternate ridge and gutter form, the ridges being notched at regular intervals. It is claimed for this system that it is a continuous flow system, that no land treatment of the effluent is required, that the effluent is good, and that the filter-bed has a filtering capacity of 1000 to 2000 gallons per square yard per 24 hours. In the Candy system, the sewage, after having been passed through a grit chamber, is evenly distributed on ærobic contact beds by patent "sprinklers." In order to re-aërate the beds the action of the sprinklers is intermittent, in that they cease acting for a few minutes at frequent, periodic intervals, which action is produced by siphon action. The materials of the contact beds consist of broken brick and other like substances.

The Ducat Filter-bed.—The principle of the bed is to produce oxidation of the sewage by causing it to drip upon the filter-bed in drops, the sewage being distributed from the top of the filter-bed by means of patent automatic tipping-troughs. No preliminary treatment of the crude sewage is employed. The effect of the free movement of air in and through the filter enables the ærobic organisms to freely attack and purify the sewage. The filtering material consists of stone chips, cinders, pebbles, gravel, or other like material. The effluent is clear, colourless, and odourless. It is capable of acting perfectly upon 250 gallons of sewage per square yard per 24 hours. The results of its operation at Hendon are admirable, and it is comparatively inexpensive to instal. It ought to be termed a bacterial filter.

Scott-Moncrieff Process.—This is also a continuous process, and is in operation at Caterham Barracks, where it deals with the purification of about 16,000 gallons of sewage daily. The features of the process are these: the sewage is passed into one end of a tank, called by the inventor a "cultivation tank." The liquid portion of the sewage passes upwards through a perforated grating, which forms, as it were, a false bottom of the tank, and which arrests the larger solids. It

then passes through a layer of flints laid on top of the perforated grating, filling the tank until it rises to the level of the outlet, which is placed about 2 inches higher than the level of the entering sewer. It is then passed through a series of wooden trays each containing a layer of coke in pieces about the size of horse-beans, and thence to an irrigating plot. The sewage thus undergoes subsidence, screening, coarse filtration, and fine contact during the course of the continuous flow. The effluent is clear, colourless, odourless, and non-putrescible. There is a minimum amount of sludge formed. From analyses of the effluents, it has been shown that there is considerable reduction in free and albuminoid ammonia and in oxygen consumed, and that nitrification takes place quickly in the wooden coke-trays. The sewage from the cultivation tank contains about 35 parts of ammonia per 100,000, and the effluent from the trays, about 29 parts of nitric nitrogen (in nitrites and nitrates) per 100,000. It is claimed for the process that it is capable, by continuous flow, of treating and purifying one million gallons of sewage per acre of tray-area in 24 hours.

Another filtering medium which has been used experimentally in Lichfield for the purification of the day-sewage is coal. The experiments made there on the large scale demonstrated an instant reduction in the effluent of albuminoid ammonia and of oxygen absorbed, but that no nitrification took place until some weeks after the coal filter-beds were in operation. The coal-filter was constructed by filling an excavated area of ground of a depth of 5½ feet with coal to a depth of 5 feet, the bottom of which was laid with drains. The sewage, after the addition of alumino-ferric lime, and after being passed into precipitation tanks and freed from suspended matter, is then passed through the coal filter-beds, composed of particles of sizes from above downwards of ⅝ths to ⅛th of an inch. The results of the treatment are shown in the following analyses by the Public Analyst of Staffordshire.

TABLE XVIII.

Parts per 100,000.

Constituent.	Tank Effluent.	Coal-Filter Effluent.
Total solids	116·00	155·00
Free and Saline Ammonia	7·35	0·016
Albuminoid Ammonia	0·33	0·046
Nitrogen as Nitrates	0·00	7·000
Chlorine	24·50	22·10
Oxygen absorbed in four hours, 80° F.	7·36	0·243
Appearances	Black	Clear and colourless
Smell	Very offensive	None
Reaction to litmus	Slightly alkaline	Neutral

In Massachusetts, sand is used as the filtering medium, but the rate of filtration is only 100,000 gallons per day per acre.

Area of Filter-beds.—The extent of superficial area of filter-beds required in the bacterial process for the treatment of sewage per 1000 of population is not yet finally decided. Kaye Parry is of opinion that to obtain a good effluent of a previously clarified sewage, two acres

of artificial filters for every million gallons of sewage per day are required. Baldwin Latham has estimated that the probable cost of artificial filters for Manchester would amount to £300,000 without including cost of purchase of land, working expenses, and renewals. A fair estimate of filter-area may be reckoned to be half an acre for a population of 1000 or 1500. At Barrhead where the system has been installed to treat the sewage of 10,000 persons with a daily dry-weather sewage flow of 200,000 gallons, the total area of contact beds is 3 square poles 5 square yards.

Sludge or Deposit in Septic Tanks. The remarkable feature in the bacterial treatment is the large disappearance by natural agencies of the sludge which is formed in the other processes. Although the Exeter tank has been in operation for more than four years, it has been found that the floor of the tank was but thinly covered with a fine deposit. At Barrhead, where the system has been working for some years, the deposit has formed to a depth of 30–36 inches at the inlets to the septic tank, grading downwards to 12–14 inches at the outlets, the deposit being very soft, and black in the colour.

Effect of Storm Water on the Process.—The English Local Government Board has framed certain rules for the works to be constructed for any system of purification, with reference to storm water. The Board demands that provision shall be made as follows :—

1. To treat fully as ordinary sewage one volume of mixed sewage and storm water equal to three times the daily dry weather flow;
2. To deal with the excess of storm water up to six times the dry weather flow, either by passing it through a special and separate storm filter, or by delivering it on a special area of prepared land other than that in use for the treatment of the effluent from the ordinary tanks and filters. If such a storm filter be provided, it should be of sufficient area to permit a rate of filtration of 500 gallons per square yard in 24 hours ;
3. That fixed bye-pass weirs should be constructed which will only come into action when the sewage is diluted with five volumes of storm water.

Storm water being a variable quantity might, at first sight, be considered to be a disturbing factor in the efficiency of the bacterial process, in respect that the increased velocity of flow of the sewage would prevent the organisms to exercise their action. But in a proper installation, such increase of velocity is but trifling, and influences but little, if at all, the results. In the Barrhead works, the trade effluents do not constitute any part of the sewage, but storm water is included, and provision is made therefor up to two-thirds the requirements above indicated. The works were constructed to serve a population of 10,000 persons and to deal with a maximum flow of sewage of 400,000 gallons per day, the dry-weather flow being reckoned as half that quantity. The regulation of the rate of velocity of sewage through the works being placed at the outlet from the septic tanks, deposit or sediment is not likely to take place at the inlet, as would be the case if matters were reversed. As has been mentioned, the very opposite of this anticipation has been realised. With a volume of sewage three times greater than the dry-weather flow, or 600,000 gallons per day, the velocity in the tanks is only $1\frac{7}{8}$ inches per minute, and with a volume six times greater, or 1,200,000 gallons, $3\frac{3}{4}$ inches per minute, either of which velocities would be incapable of

disturbing any solid matter which may have collected at the bottom of the tanks, or of dislocating the thick, tough layer of scum on the surface of the fluid contents.

Effect of Sewage Purification Processes upon Pathogenic Microbes.—What is the fate of pathogenic organisms in purification processes? The view usually held, that in the fierce struggle for existence they succumb to the greater activity of other organisms, must be modified in view of recent researches. It has been proved beyond doubt by Houston and others, that certain pathogenic organisms come unscathed through any of the foregoing processes. Houston, founding upon experiments conducted for the recent Sewage Commission, affirms "that it is doubtful if any bacterial process in practical operation at the present time, 'treats' or 'detains' the sewage for a sufficiently long period to allow of the complete destruction of all the pathogenic germs by bacterial agencies."[1] From his experiments upon the operation of the process at Barking and Crossness, he points out that *B. coli communis* and *B. enteritidis sporogenes* are nearly as plentiful in the effluents as in the crude sewage.

Respecting *B. Typhosus* and *B. Choleræ Asiaticæ* the same has not yet been proved to demonstration. They are, however, less hardy and resistant than the former. From the experiments of Andrewes and Lewes in 1894,[2] it seems well established that ordinary sewage does not constitute a congenial medium for their life and growth; indeed, even in the best circumstances, their life in sewage is limited but to days. On the other hand, since *streptococci* are abundantly found in effluents from bacterial beds—*streptococci* being comparable in resisting power with the organisms of enteric fever and cholera—it must be presumed that these latter will also survive the bacterial treatment and pass by the effluents. We have been able to corroborate Houston's results with respect to *B. coli communis* and *B. enteritidis sporogenes*. In the water of a small stream into which the effluents from coarse contact beds of an installation are allowed to flow, these organisms were found by the author in great abundance.

Conservancy Methods.

Notwithstanding the existence of a water-borne system of sewerage in a populous place, the solid refuse from houses, shops, streets, etc., remains to be disposed of. In smaller populous places, the disposal of refuse remains either in the hands of the local authorities, or is let to a contractor. In either case, it is a too common practice to collect the refuse, which is of the most miscellaneous character, at a dumping-ground in the vicinity of the town, where the combustible material is burned in the open, the contents of privy-middens and stable litter being sold for agricultural purposes. Such a practice is objectionable from the point of view not only of amenity of the neighbourhood, but also from the existence of foul odours which proceed from such depôts. In many of the older populous places, where different methods of refuse-collection have been in operation at

[1] *B. M. J.*, vol. ii. Aug. 18, 1900.
[2] *London County Council Report*, 1894.

different periods, the contents of privy-middens, ash-bins, etc., require to be collected. The problem is solved by the local authorities charging themselves with the duty of collection at short intervals of time. By the establishment of municipal depôts, to which the refuse is carted

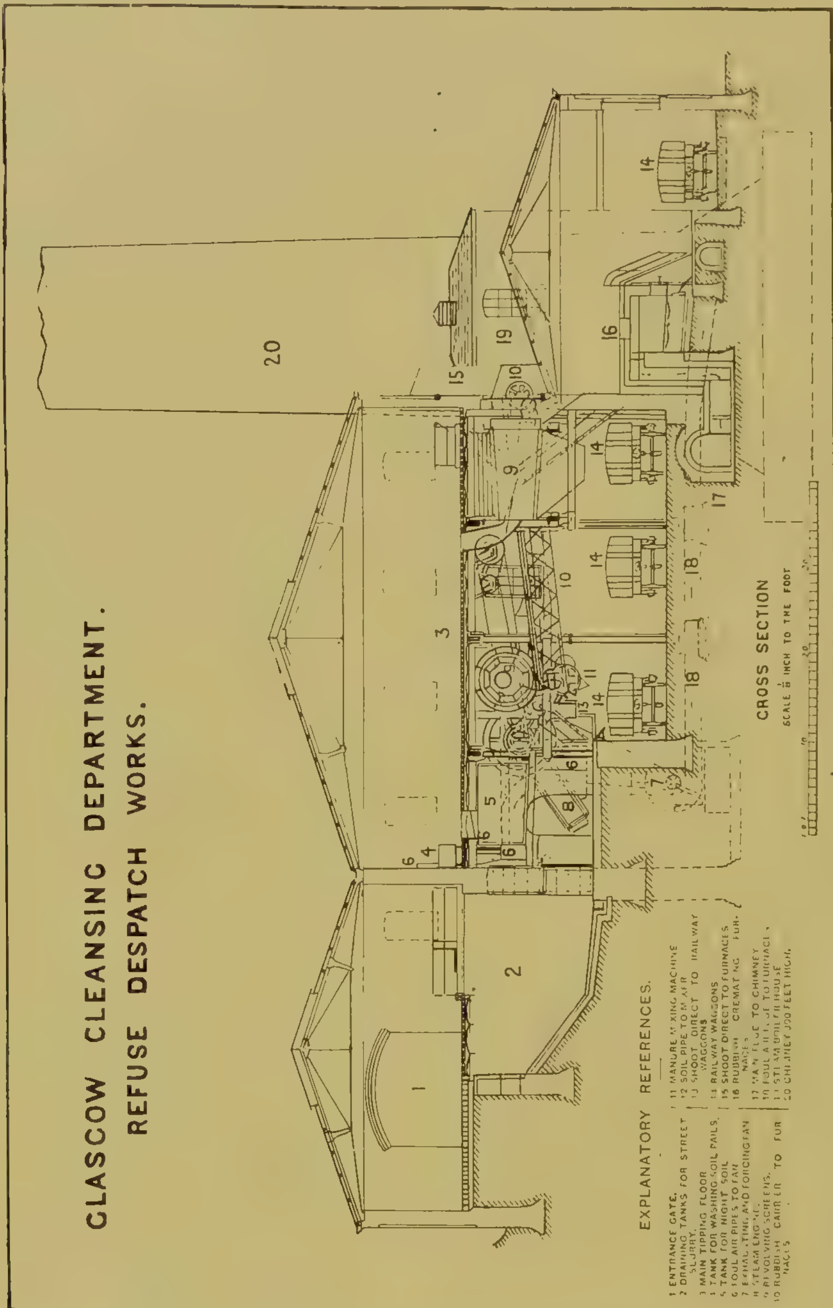

Fig. 215.

on collection, the manurial products are sold separately for agricultural purposes, all other débris which has a marketable value, as bottles, solder of tinned vessels, scrap iron, etc., is sold, and the remainder is disposed of by cremation in furnaces. In this way, hundreds of thousands of tons of refuse are got rid of yearly. Moreover, such works can

be carried on at comparatively small expenditure, since all the heating power necessary for steam-raising and electric lighting in the works is obtained from the cinders and unburnt coal from the ash-pit refuse. Most large populous centres are now provided with, or are now instituting, these crematory furnaces; indeed, up to the end of 1900, about 100 communities in Great Britain were employing incineration as the chief mode of refuse disposal. Such works have now been carried to a high degree of perfection. By suitable planning, the different parts of the works are arranged on different levels to afford the greatest facility for working. By means of a roadway, the refuse is carted to the highest level. The semi-liquid, or pasty mud from the streets is dumped into pits to permit of the draining away of the excess of water, after which the solid mud—manurial of itself—is further mixed with the fæcal contents of privy pans to form agricultural manure. Stable litter is similarly disposed of. Ordinary house-refuse from ash-bins and ash-pits is passed into a shoot, at the bottom of which is an endless travelling belt, by which the ashes and other material too large to be screened by a rotatory circular screen, is passed on to the incinerators. During their passage along this belt, marketable products are picked off by hand, for subsequent treatment and disposal. In the process of incineration to which all that now passes by the endless belt is subjected, it is important that fine dust should be got rid of, as it tends to form into a cake and thus hinders combustion. This is got rid of by the above rotatory screen. The incinerating furnaces are fed from the top with the material described and are capable of reducing the weight of the refuse to 30 per cent. of the original weight. The substance left in the furnaces is a mass of slag-like clinker, which when broken up by a machine into different sized pieces is used for pavement- and road-making, or when ground into fine powder by another machine and mixed with lime, forms excellent mortar for building purposes. Enormous heat is generated in these incinerators, temperatures of 2000° F. and upward being the rule. When such can be utilised for steam raising, enormous heating power is obtained. Provision is usually made in these works for the consumption of the smoke and fumes from the incinerating operations, by passing them over the fire and heat of the furnaces to branch flues which communicate with the main flue. The chimney by which the products of combustion are carried off, is usually about 150 to 180 feet in height. In this way, then, is the refuse of large populous centres got rid of safely and expeditiously, and, on the whole, economically. Instead, however, of disposing of all ash-pit refuse in this way, the Corporation of Glasgow leased a tract of useless peat-bog for the purpose of putting down thereupon the manurial street sweepings, etc. In a few years the whole tract was reclaimed and converted into good arable land, from which excellent crops have for years been obtained. This experiment at Fulwood near Johnstone, is being repeated on a like tract of land about fifteen miles to the north-east of the city.

The privy-midden system in populous centres is contrary to good sanitation. It has been recognised that such places as adjuncts to dwellings are at least maladorous, not to speak of their being a

positive danger to health when decomposition develops, which happens quickly. The privy therefore should give place to the water-closet, and the midden or ash-pit to the ash-bin. There cannot be any doubt that expeditious removal of the contents of these to the sewer and to the incinerator respectively is more conducive to the public health than the present practice. Offal from slaughter-houses, from fish- and other shops, like the ash-bin refuse, ought to be removed daily, and may be economically disposed of after suitable treatment as manure. Street cleanliness ought to be a feature of populous centres. By means of street orderlies in busy streets or centres, horse and other droppings should be swept up and placed in small receptacles sunk in the edge of the roadway, which should be emptied daily. Streets ought not to be swept when dry on account of the enormous clouds of dust containing pathogenic organisms, which, doubtless, are raised, as some of the dust finds its way into the nearest inhabited dwellings. To save the double labour of watering first and mechanical sweeping afterwards, Glasgow has adopted the plan of washing the streets during the night by means of hose-pipes. This will in all likelihood effect a large improvement, and so far as the experiment has gone it has done this, but the binding material of the granite setts is being also washed away. What the result will be upon the deposition of solids in the sewers it is impossible yet to say, but it is not too much to predict that there is likely to be increase of sediment in certain sewers owing to the increased amount of heavy solid matter which is thus being thrown into them in a state of temporary suspension. Moreover, to clean the streets by this method requires more water than most populous centres can always afford, or than some others can well spare even at any time.

FIG. 216. — Moule's Earth - Closet. Introduced by the Rev. Mr. Moule. The supply of earth is contained in the hopper seen at the back, and the necessary amount of dry earth may be projected into the pail by pulling the handle to the left of the figure.

In the absence of a water-carriage system, excreta must be got rid of in another way. The most primitive method is the privy-midden system, wherein the first-named convenience constitutes a part of the second, in respect that the discharges deposited in the one are allowed to mix with the ashes, food débris, etc., of the other. They are, how-

ever, foul-smelling receptacles, and should not be tolerated in populous places. In circumstances where some arrangement of this kind cannot be avoided, the two conveniences ought to be separated in the sense that the contents of each are removed separately; those of the privy by pans, which when removed more or less full under air-tight covers are replaced by empty and cleaned pans, and those of the ash-pit or midden, in the night by scavengers, and at short intervals of days. The ash-pit should not be permitted in a populous place to be placed nearer to any dwelling-house or occupied apartment than twelve feet. It should be roofed over to prevent the contents becoming sodden by rain, and thus so far to hinder putrefaction; it should have an impervious floor to prevent soakage of sub-soil with putrescent liquids; and it should not be commodious, so as to compel frequent removal of contents.

Earth-Closets.—However much better earth-closets would be than the pan-system just mentioned, their use is prevented in towns because of the difficulties of procuring easily or cheaply the earth necessary for their usage. At the same time, they have a distinct field of usefulness; as, for example, in connection with isolated houses, mansions, and smaller institutions, or in such circumstances as those in which a gravitation supply of water cannot be obtained at all, or only at unreasonable cost. The credit of the institution of the earth-closet is due to the Rev. E. Moule. Not only does the use of earth exercise a deodorant effect upon excreta, but dry decomposition without putrefactive odour is produced so long as the earth is dry; and if the mixed earth and excreta are further dried, the mixture may be used over and over again, to form ultimately a valuable manure. The best kind of earth to use is comparatively dry garden or field humus. Sand or clay are much less serviceable, the former because of the want of deodorant properties, the latter because of its stiff, unmixable character.

FIG. 217.—The Earth-Closet. British Sanitary Company's Model. The earth is introduced into the pail or receiver by the mechanical action of a lever which is set in operation by the user.

Liernur's System.—This system, which has been adopted in some populous places in Holland and in Trouville, France, requires two different sets of channels to be constructed, viz., one set for the convection of storm water, the other for household excreta. The motive power for conveying the excreta from houses is compressed air. The excreta of each house finds its way into a tank, and these tanks are connected by means of pipes with the central air-compressing machinery,

by means of which the contents are periodically drawn to the works owing to the vacuum produced in the pipes. At the works, the excretal compound is reduced by boiling and evaporation to a dried condition called *poudrette*, which is a valuable manure estimated in value at from £4 to £5 per ton. In the installation at Trouville, which has to deal with the night-soil and other household liquids of 20,000 persons during the season (Trouville being a watering-place), it is expected that from the dried manure produced an income will be derived to largely meet, if not indeed to fully cover, the working expenses.

CHAPTER IX.

PREVENTABLE DISEASES.

SANITARY science or Preventive medicine has as one of its chief objects the prevention of disease *ab initio*, and of the spread of certain communicable diseases, by removing the conditions by which they may be generated or propagated. In order to secure this end, all civilised States have made important enactments which operate not only within their own borders, but also in the relations of each to the others, with respect to the specific infectious and contagious diseases. In respect of the class of infective diseases, and, indeed, of other preventable diseases, such as scurvy in seamen, and of inhalation or ingestion of substances used in trade operations which are inimical to health, an immense and complicated machinery has been erected and kept in motion for their prevention. The State obviously only deals with those causes which are beyond ordinary individual control, such as the effects of employment on children and women in factories and workplaces, or which operate by carelessness in one or another form, such as the spread of infective diseases, the sale of food unfit for human use, etc. These, however, are capable to a large extent of being controlled and regulated by regulations enacted by a controlling authority, and, especially, if disobedience thereto is followed by penalties. The object of State control in this connection is the protection of the mass of the people against the carelessness and negligence of the individual. The preventable diseases are incited and initiated by a variety of causes, among which may be named overcrowding and filth, insanitary conditions of sewage-disposal system, and contact with the infective sick or with infected material. To this class also belong those diseases which are communicable from animal to animal and from animals to man. The chief characteristic of the specific preventable diseases is their communicability by a specific contagium or infective agent, which, although well recognised for many centuries, since, indeed, the institution of the Mosaic Code, only became intelligible since the discovery of their microbic origin. It is not necessary to consider the various theories which have been propounded from time to time regarding the causal factors of these diseases, since the discovery of microbes amply accounts for all their phenomena. Koch's rules whereby an infective disease should be so designated only apply, it must be understood, to several of these diseases, because in respect of some of these, specific micro-organisms have not yet been discovered and isolated. Koch's requirements are as follows :—

(1) A micro-organism must be found in the blood or tissues of the person or animal that is suffering, or has died from the disease; (2) this microbe taken from the body must be capable of artificial cultivation in suitable culture media,

in a series of generations, out of the body, with no possibility of any other microbe being introduced during the process; (3) the microbe from one of these cultures, on being inoculated into the body of a healthy animal, ought to reproduce the same phenomena of disease as those exhibited in the animal or person from whom it was originally taken; and (4) the microbe must be proved to have multiplied in the body of the animal inoculated.

The principal preventable diseases are the following, viz.: *Small-pox, chicken-pox, scarlet fever, measles, rötheln or German measles, typhus, enteric, relapsing, yellow,* and *continued fevers, cholera, influenza, whooping-cough, diphtheria, erysipelas, puerperal fever, pneumonia, mumps,* and, with a limited infectivity, *tuberculosis.* These may be considered as of the infective type. Glanders, anthrax (known as wool-sorters' disease and malignant pustule in man), foot-and-mouth disease, venereal diseases, Egyptian and other forms of ophthalmia, leprosy, rabies, and to some extent malaria, may be reckoned as of the contagious type.

Types of Micro-organisms.—These may be divided into the following morphological types, viz.:—

1. *Micrococcus*, comprising the *diplococcus*, *sarcina*, or *tetracoccus*, *streptococcus*, *staphylococcus*.
2. *Bacillus.*
3. *Spirillum.*

To the first form belong the micro-organisms of fowl cholera, swine fever, measles, scarlet fever, small-pox, cow-pox, foot-and-mouth disease, pneumonia, erysipelas, puerperal fever, and of other diseases; to the second, those of anthrax, tubercle, glanders, enteric fever, cholera, diphtheria, tetanus, leprosy, plague, and of others; and of the third, that of relapsing fever.

Nature of Infective Material.—Whether this is known by the names of *effluvium*, *miasma*, *influence*, *virus*, *fomites*, *infection*, *contagium*, or by any other name, infective matter is essentially particulate in character, and is capable of being borne by or upon different media, as air, food, clothing, and various others. It is composed of micro-organisms or their spores or both. Being particulate, therefore, it obeys natural laws; because of its lightness, it is easily air-borne when in a dry condition, but it is held in retention by moist surfaces; it cannot penetrate any interposing barrier, even of paper, and much less, walls and doors. Destruction of infective material, therefore, resolves itself into annihilation of organisms and spores.

When pathogenic organisms gain a foothold in the body they exhibit elect seats of operative activity. Upon this basis, they may be divided into three classes, viz.: (1) those which mainly involve the skin; (2) those which invade the upper internal mucous tract of pharynx and air passages; and (3) those which implicate the lower mucous tract, intestines, etc. To the first class belong chicken-pox, small-pox, erysipelas, scarlet fever, measles, German measles, and others, this class being known as the exanthematous group; to the second belong diphtheria, foot-and-mouth disease, whooping-cough, mumps, ophthalmia, influenza, pneumonia, and pulmonary tubercle; and to the third, cholera, enteric fever, yellow fever, and puerperal fever. Several diseases of this type refuse to be so arbitrarily classified, in respect that some of them invade more than one of the above tracts; but while the infective material in each infective disease may be found in more than one of the discharges of the patient, it is most abundant at the elect seats of operation. The habitat of micro-organisms

in the body is determined by their life-history; for example, the *B. diphtheriæ* cannot grow without a plentiful supply of air, hence it is found in those situations most calculated to meet this requirement. The evil results which follow the development of pathogenic organisms in the body are due to the products which they form out of albuminous substances in the course of their growth and multiplication. These being derivatives of albumen have been called *albumoses*, and because of their poisonous action on the bodily functions, *toxines*. Such albumoses or toxines may be formed directly in the blood itself, or they may be absorbed into the blood from the tissues. In diphtheria, for example, they are formed in the mucous membrane of pharynx or air-passages, and after absorption produce profound physical depression and it may be, after-paralysis of some part of the body; the toxine formed by the *B. tetani* produces cerebro-spinal irritation, evidence of spinal disturbance being shown by the convulsive contraction of the masseter and other muscles of the lower jaw.

While communicable diseases may be seen in isolated cases, more usually they betray their presence by several persons being attacked within a limited short time. They are thus said to be of one of three forms, viz.: the *epidemic*, the *endemic*, and the *pandemic*. An epidemic disease may be defined as one which, independent originally of local causes, attacks a number of persons in a population within a short time. The cause, therefore, belongs more to the people than to the place. An endemic disease is one which is dependent upon local conditions, attacks individuals in communities, and is more or less continuously prevalent. The cause has its origin more in the place than in the people. A pandemic disease is one which attacks the bulk of the population of a country, or numbers of population of different countries, about one time. Of the first and last it may be said that the infective material is conveyed from man to man by intercommunication, and from nation to nation by trade routes or by atmospheric agency.

Influence of Climatic Conditions on Infective and Contagious Diseases.—Climate may be defined as a resultant of different factors, as annual range and extremes of temperature, atmospheric pressure, humidity, prevalent winds, exposure, and certain other local conditions. The effects of climatic conditions manifest themselves markedly with respect to certain classes of diseases, but so far as is known, not with respect to others; for example, pulmonary ailments mostly prevail in winter and spring when temperatures are low, and infective diseases of the abdominal type, mostly in summer and autumn. But climatic conditions also exercise a determining influence on the infective type of diseases generally.

Small-pox prevails most in winter and spring, least in the other seasons. The temperature has a notable influence on its spread and decline. Below 50° F., the disease tends to spread, above that temperature it tends to decline. Scarlet fever prevails most in the last six months of the year, the maximum being in the December quarter. A temperature of about 60° F., favours the extension of the disease, a fall to 50° F., tends at once to arrest it. Measles is a disease chiefly of the months of November, December, January, May, and June.

The most favourable temperature for its spread is between 45° and 50° F., while above 60° F., or below 40° F., it receives a check. Babès isolated a micrococcus which he believed to be the causal factor, but his conclusions have been questioned. Typhus fever prevails most largely at those seasons of the year when the poor and uncleanly live in overcrowded rooms. It therefore is more common in the winter than in the summer months, although there is a rise in the mortality in July, explainable in some cases by the same conditions. The infective matter — for as yet no specific micro-organism has been discovered—although very virulent within close range of those affected, is neutralised by plentiful supplies of air. From the patient a characteristic odour is exhaled, which is apt to adhere to clothing. Typhus fever more than any other disease of the infective type has succumbed to the influence of improved sanitary environments. It is now a comparatively rare disease. Enteric fever is most common in the autumn months. It would therefore appear that the climatic conditions then prevalent are most favourable for the development of the Gaffky-Eberth bacillus. It is more a disease of rural than of urban communities, and epidemics in the latter are, in many instances, imported from the former. Whether this fact is alone due to the less attention which is given in rural districts to the disposal of excreta, it is difficult to say, but there is little doubt that it is an important factor in its causation, by reason of consequent pollution of water-supplies. October is the month of its maximum prevalence. The organism of the disease is usually conveyed by infected milk or water, but in privy-midden towns where the disease is said to be more prevalent than in ash-bin towns, there are good grounds for believing that the common house-fly and other winged insects are important factors in the propagation and extension of the disease, because of their foul-feeding habits, and consequent convection of infective material to domestic food-supplies on their antennæ, wings, or legs. Since the infective matter is thrown out of the body chiefly by stools and urine, great care should be exercised in their disinfection. Summer diarrhœa, too, prevails more extensively in summer and autumn than in winter. The *B. enteritidis* of *Gœrtner* is most commonly found in the months of the former seasons. Yellow fever is confined to climates very different from that of these islands. Its range of distribution is limited to the West Coast of Africa, the West Indies and Gulf of Mexico, some parts of South America, and to limited tracts of the Atlantic and Pacific sea-boards of North America. Within these limits it is usually endemic. Strangers are more liable to be seized than natives, since the latter have become acclimatised. Immunity is only established after long residence, and even then is but imperfect, although second attacks are comparatively rare. A temperature below 65° F., prevents the diffusion of the disease. The spread of the disease in Sept. 1865 among the population of Swansea from a ship which arrived in port infected with yellow fever must be attributed to the high temperatures which prevailed at the time. Twenty inhabitants of the town were seized on that occasion. The specific micro-organism has not yet been isolated ; more than one has been declared to be the causal factor, but not one has been proved beyond doubt.

In 1897, Sanarelli described the *B. icteroides*, and Sternberg in 1890, the Bacillus x, both of which were suspected at the time to be the *causa causans* of this disease. But Reed and Carroll[1] showed that they belonged to the hog cholera group of the coli bacilli. Durham and Myers studied this disease, from which the latter unfortunately lost his life. A full account of their researches is yet to be given, but they were unable to isolate any organism which could be absolutely shown to be the specific micro-organism of the disease. Reed, Carroll, and Agramonte, at the Pan-American Medical Congress in 1901, presented a communication embodying their reasons for the belief that the mosquito, *Culex fasciatus*, serves as an intermediate post for the parasite of yellow fever. The whole subject is still under investigation.

Relapsing fever—sometimes called bilious typhoid or famine fever —is much more infrequent in its incidence in this country than most of those already named. It has a noteworthy coincidence both as to time and place with typhus fever, and like it, seems to be contingent upon privation and overcrowding. The causal factor is the *spirillum Obermeierii*, which is so named after Obermeyer who first discovered it. It cannot be successfully inoculated in the lower animals except in the anthropoid apes. Relapsing fever has not visited this country in epidemic form since 1870–71. It is both contagious and infectious. In some epidemics, notably the last, laundry-women who washed the clothing of those affected were seized with the disease. It would appear to confer but a passing immunity on those attacked.

Cholera, in this and most other countries, is essentially an epidemic disease, although in certain countries as India, it is endemic. It causes a high mortality. In many outbreaks the line of infectivity could be tracked by trade routes, or by intercommunication between an infected and a non-infected people. It is more prevalent in the warmer seasons of the year; but to this general rule there are marked exceptions. Great Britain and Ireland have been subject to outbreaks of it on four different occasions, viz.: in 1831, 1848, 1853, and 1866, with, in addition, a very limited outbreak in 1893.

The epidemic of 1831 had its origin in an infected ship which arrived in Sunderland from Hamburg in October 1831, from which it rapidly spread through the country. It broke out in Glasgow on 12th February 1832, and before it disappeared, it was estimated to have seized one in every six families of the population, and to have caused one death in every thirteen families. The total number of deaths was 3166, of which 1419 were males and 1747 were females. The total number of cases known to the authorities up till November 5 of that year, was 6208, or 1 in 32½ of the entire population. The mortality was chiefly confined to the intemperate, the dissolute, the ill-fed, and ill-clothed part of the population, but it did not overlook the better-conditioned classes. It attained its maximum in August.[2] The total mortality in England from this epidemic, according to Hirsch, was 30,924 deaths. The epidemic of 1848 began after the arrival of an infected ship from Hamburg at Hull in October of that year. It quickly spread to London, Edinburgh, and other places, and arrived in Glasgow in November 11. The last case reported in Glasgow was on March 22, 1849. The epidemic, therefore, lasted in that city for four months and eight days. The number of deaths was 3923. This epidemic, unlike the former, attacked chiefly the better classes. The total mortality in England was estimated at 53,293. The outbreak of 1853 also came from Germany, several English sea-ports being almost simultaneously attacked. It appeared in London in August, and in Glasgow about the middle of December.

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[1] *Jour. Exper. Med.*, Dec. 1900.

[2] *Vide* Paper on "The Epidemic History of Glasgow, 1783–1883," by the Author, *Proc. Philosoph. Soc. of Glasg.*, vol. for 1885–1886.

and continued in the latter city more or less for a whole year. It culminated in the month of August. The total deaths in Glasgow, so far as known, was 3885, of which no fewer than 1023 occurred in August. The total deaths in England and Wales was estimated at 20,097. The seizure of 1865–1866 was much more limited both in numbers attacked and in mortality. It was imported originally to Southampton from the Mediterranean in July. It reached Glasgow in 1866, and the number of the deaths in that city only amounted to 53. The total mortality in England and Wales was 14,378. The outbreak of 1893 was limited to a few seaport towns on the south-east coast of England. The number of cases was small.

The freedom of this country from outbreaks during the last 20–30 years must be attributed mainly to better water supplies and improved sanitation, since the facilities of intercommunication with other countries in which it is endemic or epidemic have become enormously multiplied. Cholera is essentially a water-borne disease. This is well illustrated in the Hamburg outbreak (*vide postea*). The infective matter is almost solely confined to the intestinal discharges. Stools, therefore, must be thoroughly disinfected, or preferably, cremated after admixture with sawdust. There can be no doubt that its causal factor is the *B. choleræ Asiaticæ* which was discovered by Koch. The organism is of the form of a slightly curved, slender rod with pointed end, not unlike the comma of German type, hence its more common name, *B. Kommæ.* It probably would be more correct to describe it as a *vibrio*, which forms the segment of a spirillum. The vibrio or spirillum is the shape assumed by the organism when three or more organisms are joined together end to end. It measures in length from $\frac{1}{8}$ to $\frac{1}{3}$ the diameter of an ordinary red blood corpuscle. It can be easily cultivated ærobically on ordinary culture media, but it is capable of growth under anærobic conditions, from which it appears to gain virulency but to lose power of resistance to adverse conditions. It thrives abundantly in sewage and contaminated liquids, but dies after a few days when placed in pure water, doubtless from want of nutrient material. It is readily destroyed in acid media, therefore, under normal conditions of the stomach, it is destroyed by the acid gastric juice.

Influenza is a typical pandemic disease. During the last half-dozen centuries it has broken out and spread over entire continents. It has within the last few years ravaged the countries of the world. It was known to exist in Siberia in May 1889, and by the end of December of that year, every European country had been attacked ; and within six months thereafter, most of the countries of the world.[1] It would appear to be uninfluenced by meteorological conditions, for it spreads with as much freedom in Iceland as at the Equator. While in not a few instances the line of infectivity may be tracked from place to place, and from country to country, in others it cannot be defined ; but there is great reason to believe that like other infective diseases it is propagated by infective persons or infective things, and obeys the same natural laws. Whether or not there is a direct causal relationship between its outbreak in man and in animals, it is frequently coincident with the existence of a disease in horses called "pink-eye." This coincidence has so frequently been found that it would seem to point to a relationship between them, although the precise character of that relationship is not yet well understood.

[1] *Vide* Paper on "Influenza" by the Author, *San. Jour.*, April 1892.

Influenza is both contagious and infectious. Like other infective diseases, its severity of type varies; in some epidemics, its original form is comparatively slight, but it gains in intensity during the progress of the outbreak. Pfeiffer has isolated a bacillus from the purulent bronchitic sputum of those attacked, which is generally believed to be its causal factor. It is a fine, short rod, having rounded ends, is frequently found in chains, and measures 0·5 micro-millimetre in length. It is easily stained with carbol-fuchsin. Much remains to be known regarding the habitat of this organism and the modes of its propagation. So far as is known at present, it chiefly enters the body by the air-passages.

Whooping-Cough is commonly a disease of the early years of life, but is not unknown to attack those of maturer ages. The highest mortality obtains within the first five years of life. Of the total deaths from this disease, about 40 per cent. occur within the first year, about 70–75 per cent. within the second, and from 90–96 per cent. within the fifth year of life of those attacked. It is both contagious and infectious. The channel of attack is the air-passages, since its initial symptoms are those of catarrh of the upper mucous tract. The infective matter is chiefly centred in the bronchial and nasal secretion. This disease, along with measles, accounts for a higher mortality than all the other zymotic diseases put together, and not uncommonly one is the sequel of the other, since the mucous membrane left weakened by the one affords a suitable culture-ground for the micro-organism of the other. They have many times been known to run concurrently. It does not appear to have any strongly marked relationship to seasonal influences. The higher death-rates which obtain in certain seasons over others seem to be determined more by complications than by the influence of the disease itself, although various complicating diseases are engendered by the existence of the whooping-cough. It may however be said generally, that the highest mortality prevails in the first three months of the year, and the lowest, in the summer months; but this is, doubtless, in large measure due to the pulmonary complications which are apt to arise in the more inclement conditions of the winter and spring months. Whether age confers a resisting power against the disease is a question difficult to determine. While it is well established that adult life is but rarely the subject of attack, it is a matter of some uncertainty whether this apparent immunity is not due to unrecognised attacks in infancy or childhood. If, however, an isolated community be attacked, the disease finds its victims in children and adults alike. In one island on the west coast of Scotland, for twenty years before 1892 the disease was unknown; but in that year it was introduced, and of a total population of 380 persons, 114 were attacked at all ages up to twenty. A micro-organism has been found in whooping-cough, but it is not yet clearly proved to be the intimate causal factor. As bearing upon the infectivity of a common cold, it has been observed of inhabitants of remote islands who are cut off from intercourse with the mainland for the major portion of each year, as in St. Kilda and other islands similarly circumstanced, that whenever a ship visits the island, numbers of the inhabitants are seized with a catarrhal affection

of the naso-bronchial tract, which in St. Kilda at least, is known as "the strangers' cold."

Diphtheria, a name given by Bretonneau in 1826 to a disease which was formerly called angina, and which was first described by Aretæus the Cappadocian about eighteen centuries ago, is due to a micro-organism which chiefly attacks the surface of the upper mucous membrane of the air-passages, or abraded skin surfaces of other parts of the body. Its origin in microbic influence was first suggested by Laycock in 1858. A committee of the Royal Medical and Chirurgical Society of London appointed to inquire into the nature and cause of diphtheria and membranous croup, reported in 1879 that while certain micro-organisms were found by them in the false membrane, they did not regard them as causative agents. Oertel discovered a *coccus* which he considered to be the prime cause. Klebs in 1873 found a bacillus in the throat of affected persons, but he failed to isolate it by culture out of the body. Friedrich Löffler corroborated Klebs' discovery, and succeeded in isolating the organism by artificial cultivation. He also proved the existence of the coccus described by Oertel, but established by experiment that it was not causative of the disease. The *bacillus diphtheriæ* has come, therefore, to be spoken of as the Klebs-Löffler bacillus. It is a long, straight, or slightly curved, non-motile rod, which is thickened or clubbed at one or both ends, and which measures between 1·2 and 2 micro-millimetres in length. It stains readily by Gram's method. Associated with the Klebs-Löffler bacillus are the pseudo-diphtheritic bacillus of Löffler, which he found in 1887, and that of von Hoffmann, to which the latter drew attention in 1888. These exhibit, however, certain clinical and cultural differences from the true organism which enable them to be distinguished from the true bacillus. The researches of Hewlett and Knight have established the following points of difference. Clinically the pseudo-organisms although found in certain cases of sore throat and membranous rhinitis are not contagious, and the patches in which they are found do not tend to spread. Culturally, they may be distinguished by the following differences, viz. : (1) On alkalised potato, they form distinctly visible, cream-coloured colonies in two days, whereas the growth of the true bacillus in the same time is almost invisible; (2) With neutral litmus agar they produce an alkaline reaction, the true bacillus, an acid reaction; (3) In nutrient broth, under strictly anærobic conditions, the pseudo-organisms do not grow, whereas the true bacillus grows freely; (4) The former gives the indol-reaction with *peptone-water* only after three weeks' growth, the latter, at the end of one week. Other observers as Roux, Yersin, and others affirm however that the pseudo-bacilli are simply ordinary diphtheritic bacilli which have become attenuated in influence. Salter's observations go a long way to substantiate this latter view. By cultural treatment he succeeded in transforming the supposed non-pathogenic pseudo-bacillus into one having the pathogenic properties and morphological characters of the true bacillus, and which, when injected into guinea-pigs, operated exactly similarly to the true bacillus.[1]

From the practical point of view, therefore, it is better to treat

[1] *Trans. Jenner Instit.*, ii. series, pp. 113–25.

the pseudo-bacilli, when found in the living human body, as having the potentialities of the diphtheritic bacillus, until at least more regarding their life-history is known. Diphtheria mainly attacks the young, although it does not spare those of adult years. It attacks the female more than the male sex, and the death-rate of the former is the higher. It prevails more in rural than in urban communities, but it would appear to be on the increase in the latter; but whether this is due to increased facilities of inter-communication, to school-life, on account of its presence not being detected early, or to drain-sources, or from those combined, has not yet been definitely determined. Whether the disease in fowls known as "gapes" or roup is identical with diphtheria is also undecided, but our observations show that the presence of a false membrane in these birds is sometimes followed by a paralysed condition of the lower limbs.

From the point of view of practical hygiene it is of importance that the identity or non-identity of "gapes" or "roup" with diphtheria should be decided. Turner[1] has shown the existence of this fowl disease and human diphtheria to be concurrent in several instances. He further affirms that he has seen a farmer's wife, her son, and a daughter seized with a disease notified by a medical practitioner as diphtheria, from treating fowls which were suffering from the disease called "gapes," or "roup," or "sincup," all of which are local names for the same disease; that he has succeeded in conveying human diphtheria to fowls; and that he has seen paralysis of the lower limbs of a fowl succeed the throat affection. We can personally corroborate the last observation. The identity of the diseases is, on the other hand, denied by M'Fadyen and others. But all this points to the need for definite experimental evidence.

Diphtheria does however attack cats, and these animals are readily affected by taking milk containing a culture of the organism. There are reasons also for believing that it may be associated with certain ulcerated conditions of the udder of the cow. The experiments of Klein, which consisted in injecting a culture of the organism into the body of the cow, demonstrate that swelling and thickening follows at the point of injection; that it increases for about seven days, and then subsides; that broncho-pneumonia develops, which is followed by a vesicular eruption on udder and teats, the fluid of which contains the bacillus; and that the milk of the cow, when given to cats, gives rise to an illness which exhibits great likeness to that which is sometimes found in cats during epidemics of human diphtheria.

While diphtheria usually manifests itself in epidemic form, in certain districts it is endemic, and sporadic cases may also arise. The time of greatest mortality is in November and December, which accords with the time of greatest prevalence of epidemics of the disease; the lowest mortality period is the summer months. Atmospheric humidity, rainfall, wet condition of soil, and other factors have been indicated as predisposing conditions to its outbreak and prevalence, but no satisfactory evidence has yet been adduced in proof. The infective matter, apart from contagion from the sick, is believed to be carried, and the disease therefore to be pro-

[1] *B. M. J.*, vol. i. 1900, p. 1900; idem, p. 1506.

pagated, by air and milk, and some would add, by water. There is no proof, however, of the truth of the last. In respect of milk which has been exposed during its preparation for sale to infective matter from a sufferer, or which has been handled by a carrier or distributor who is suffering from a mild attack of the disease, the bacillus finds a suitable culture medium in which to grow; consequently many outbreaks have been traced to this cause. In its growth in the human air-passages, the bacillus forms albumoses or toxins which on absorption into the blood produce profound changes in the nervous system, of which paralysis of the palate, and even paresis of one half of the body, are not uncommon manifestations.[1] Croup is a name associated with certain symptoms of difficult, noisy, crowing respiration, which is due to laryngitis accompanied by more or less tumefaction of the laryngeal mucous membrane. But diphtheria is sometimes mistaken for croup when the location of the false membrane is laryngeal, by reason of the mechanical difficulty of respiration thereby produced. Membranous croup is not in public health law held to be a synonym for diphtheria, as it is named separately in the schedule of the Notification Act. That such membranous exudations may arise on the laryngeal mucous surface there is no doubt, as, for example, where strong ammonia vapours are inhaled; but in view of the aid to diagnosis which bacterioscopy affords, the time has arrived when the name membranous croup should be blotted out of public health nomenclature.

Erysipelas, the prime factor of which is the *streptococcus erysipelatis*, is one of the few zymotic diseases which does not by one attack confer immunity against a second, or even a third attack. The same organism has probably to do with the genesis of puerperal fever. The incidence of erysipelas is upon the skin of exposed parts of the body, due to the entrance of the organism by a breach of surface, which may be very small. It is met with all over the world, and occasionally assumes epidemic proportions. Being closely allied with scarlet fever and puerperal fever, it is found to be coexistent at the times and seasons when these prevail. It attacks by preference the male sex, but this is probably due simply to the fact that males are more exposed to conditions calculated to produce abrasions of the skin. It is most fatal in the winter months. While it once was common in hospital practice, it has practically ceased to exist therein since antiseptic and aseptic precautions began to prevail. The infective matter is chiefly found in the area of skin tissue affected. Phlegmonous erysipelas, which manifests itself by extensive and rapid destruction of areolar tissue accompanied by suppuration, is due to what is commonly known as the *streptococcus pyogenes*, which, according to recent observers, is identical with the *S. erysipelatis*, their apparent differences in action being, probably, largely owing to the nature of the tissue invaded, and in some measure also, to the type of virulency of the organism.

Puerperal fever is a communicable disease associated with parturient women. It is a somewhat unfortunate name, since in modern nosology it is used to include a variety of conditions. It ought to be distinguished by one feature, viz.: septic poisoning. It is caused by

[1] *Vide* paper by author, *Proc. Phil. Soc. Glasg.*, March 1895, "The Anti-toxin Treatment of Diphtheria."

the *S. pyogenes*. Its infective character is most marked. The infective material clings tenaciously to the clothing and person of attendants, hence the most scrupulous care and completeness should characterise the disinfection of everything and of every person in connection with a case. It has been propagated by medical men and nurses from the sick to the healthy, notwithstanding the most vigilant care and most thorough disinfection. It may arise from the air of house-drains; at least, certain cases point strongly to this source. Careful aseptic toilet of the patient, absolute cleanliness of hands and instruments, and good sanitary surroundings will prevent its inception and check its spread.

Pneumonia must be reckoned, in one of its forms at least, as a zymotic disease. By reason of its outbreak in epidemic form from time to time in this and other countries, its microbic origin was suspected. Pathology has demonstrated that the form which the disease then assumed was what is known as the croupous or fibrinous form, and that the croupous inflammation very often was confined to the upper lobe. Moreover, clinically it differed from the catarrhal form in the symptoms exhibited. But the diagnosis is rendered very difficult by the fact that marked pulmonary symptoms may initiate other microbic invasions of the body. This is true of anthrax, plague, and sometimes, of enteric fever. In one very extensive and fatal outbreak of enteric fever in Glasgow due to infected milk, many of the earliest cases had so pronounced pulmonary symptoms that the true nature of the disease was masked for a period; but as the cases progressed, it became clear and conclusive. The highest mortality from pneumonia is attained in December, but is also high during the other winter months. An epidemic of this disease prevailed in Middlesborough in the first half of 1888, attacking 1633 persons in a population of 97,000, of which 369 persons died. This is the largest epidemic which has occurred in this country. According to Foulerton [1] epidemic pneumonia again prevailed in the same town in 1900–1901, this time characterised by fibrinous lobar attacks, which, however, were not due to *pneumococcus* infection, but in his opinion, which was derived from bacteriological investigation, to a bacillus possessing all the characters of the *B. coli communis*, to which, according to Klein and Ballard, the epidemic of 1888 was also attributable. In 1882, Friedländer and Talamon discovered in croupous pneumonia a definite micro-organism which they called the *Micrococcus pneumoniæ*, and pure cultures of which injected into rabbits produced the disease. Further observations, however, showed that that organism played but a secondary part in the genesis of pneumonia, and that the true micro-organism was the *pneumococcus* discovered by Talamon-Fränkel. This organism is actually a *diplococcus*, and has been called by a variety of names, as, for example, *Diplococcus pneumoniæ* of Weichselbaum, *Streptococcus lanceolatus* of Talamon and Gamaleia, and the *micrococcus* of Sternberg. In the Middlesborough epidemic Klein found a bacillus in the tissues of those who had died of the disease, to which he gave the name of *B. pneumoniæ.*

[1] *B. M. J.*, vol. ii. 1901, p. 760.

The *diplococcus pneumoniæ* forms pairs of cocci, and are found grouped not unlike streptococci, hence the difference in nomenclature. The cocci have a distinct, lanceolate shape at each extremity, as seen in bodily fluids, but this character is lost in artificial culture. Moreover, in tissues they are enclosed in a capsule, or what appears to be a capsule, which is also lost by artificial cultivation. It is easily stained by Gram's method, whereas the organism of Friedländer is decolorised. But in respect of pneumonia generally, there are strong grounds for believing that the disease is altogether due to microbic influences. It may be that there is more than one causal factor; that is, indeed, more than likely: but the exact answer can only be given by further and more intimate study of the disease from the bacteriological standpoint.

Plague. This disease, which in the earlier centuries overran continents and destroyed millions of lives, and which last appeared with epidemic force in this country in 1665, again made its appearance in the autumn of 1900. While, however, it has been absent for so long a period from this country, it has in the interval on more than one occasion visited the continents of Europe and Asia. It is noteworthy that these outbreaks, recent and remote, have all had their origin in the East; indeed, it is believed that it is endemic in certain districts of Upper India, Southern China, Manchuria, and in Persia and Turkestan.

The Justinian outbreak in the sixth century, which worked havoc in Great Britain between the years 664 and 685, and the Black Death, which spread from Asia to Europe, appeared in Italy in 1348, in England in August, and in London in November of that year, left enormous death-tolls in their wake. It is estimated that the latter, in Europe alone, destroyed no fewer than twenty-five million persons. Becoming endemic in Great Britain and Europe between the fourteenth and seventeenth centuries, it did not become extinct in the former till some fourteen or fifteen years after the Great Plague in London in 1665. Disappearing practically from Europe for the most part of the eighteenth, it was only to be found in limited areas during the nineteenth century, and vanished from the Continent in 1844. In 1853 it appeared in Western Arabia; in 1858 Tripoli was attacked; and in 1863 a fatal outbreak of the bubonic type developed in Persian Kurdestan. In 1867 it broke out among the inhabitants of the marshy lands of the Southern Euphrates, having, doubtless, been conveyed thither by pilgrims. In 1871 it again revisited Persian Kurdestan, and in 1874, the Lower Euphrates, Tripoli, and Assyr, within four days' march of Mecca; while during 1875 and 1876 it lingered in the Euphrates valley and Bagdad. In 1884 the disease existed in Yunnan, China, and at Pakhoi, near Tonking. In March, 1894, it appeared in Canton, and by May it had reached Hong Kong. From thence it spread to India, appearing in the Bombay Presidency in 1896, and in Calcutta in April, 1898. In 1896, four cases appeared on three British ships sailing from Bombay and Calcutta; in 1897, two lascars took ill on board the *Carthage*, four and twelve days respectively after leaving Bombay, and in 1898, certain suspicious cases occurred on the s.s. *Caledonia;* indeed, one of them, detained in

hospital in Bombay, proved to be plague; the steamer *Golconda* from Calcutta and Madras arrived at Plymouth on December 24 with a case of bubonic plague on board, but the patient recovered in hospital; and the s.s. *Peninsular* from Bombay arrived on October 14, 1899, at the same port with another case on board, the patient also recovering in hospital. Since January 1899, it has appeared in both hemispheres, but to a much more limited extent than in the previous years—in Alexandria, 93 cases and 45 deaths, in May; in Oporto, 282 cases and 104 deaths, in August; in Santos and other Brazilian ports, in October, infection being carried from thence to Cardiff, Capetown, and the United States; and, in addition, in Hamburg, Lisbon, Trieste, Sydney, St. Petersburg. and San Francisco. The small outbreak in Vienna in October, 1898, arose from laboratory infection, and occasioned three deaths, viz.: of the laboratory attendant, and of Dr. Müller and a nurse who attended him during his illness. The Glasgow outbreak began in August, 1900. The total number of persons attacked was 40, and the total deaths numbered 16. The initial source of the infection remains a mystery, but the cause of the spread was the holding of "wakes" over the bodies of persons who had died of the unrecognised disease.

The causal factor of the disease is the *B. pestis*, which was discovered independently and simultaneously by Yersin and Kitasato in 1894. They both found it in the blood and buboes of affected persons. It is a very minute cocco-bacillus, which is non-motile and gives the appearance of a small squat bacillus. It measures from 1 to 2 micro-millimetres in length and about 0·5 in width. Kitasato states that at 37° C. it is motile, and Gordon, that it possesses terminal spiral flagella. It is non-sporular, and is a facultative anærobe. It stains readily with anilin stains, but the best results are obtained from the use of carbol-thionin-blue and eosin, as stain and counterstain. To examine sections for the organism, they are first stained with carbol-thionin-blue for five minutes on the slide, washed with water to get rid of excess of stain, then in water slightly acidulated with acetic acid, and then in ordinary water. It is then counter-stained with a $\frac{1}{4}$ per cent. watery solution of eosin for about half-a-minute, washed in absolute alcohol to get rid of water, cleared in xylol, and mounted in Canada balsam. The staining exhibits well-marked bi-polarism, and the bacillus seems to be enveloped in a capsule. The *B. pestis* is differentiable from those organisms which resemble it, and which moreover may be found along with it in cases of mixed infection, in that it is not capable of being stained by Gram's method, while the pneumococcus, staphylococcus, and streptococcus are freely stained therewith. It is found abundantly in the affected glands, almost as a pure culture in the earlier stages of the adenitis, but as involuted forms usually in the suppurative stage; and in the lung-tissue, the spleen, liver, kidneys, and other organs of the body. It can be cultivated easily in the ordinary media, but it grows most rapidly on blood-serum, forming slightly elevated, moist, cream-coloured growths. In gelatine it shows as an opaque, white growth with irregular edges.

Plague attacks the lower animals, and there is clear evidence to

show that it is communicable from them to man. Clemow[1] has made an exhaustive study of this part of the subject, and has shown that epidemic outbreaks occur in monkeys, in rats, bandicoots, squirrels, mice, guinea-pigs, porcupines and marmots, of the class *Rodentia*, and that dogs, cats, pigs, and sheep are also susceptible but in a more limited degree, while goats are more susceptible than they, and horses escape infection under natural conditions. With relation to man, however, rat infection is the most important. It has been definitely established that an epidemic of the disease in rats is commonly found to precede or run concurrently with the outbreak in man, and that the entrance of diseased rats into dwellings, or the handling of rats which have died of the disease, is in these circumstances the communicating factor to man. There is also some evidence to support the belief that it may be communicated from animal to animal and from animal to man by the intermediation of fleas, lice, bugs, and ants. The experiments of Montenegro of Madrid indicate that fleas, passing from the body of a rat which has died of the disease to that of a healthy rat, cause the latter to be attacked by the disease. At the same time, outbreaks of plague have occurred without manifestations of the disease in rats. In the outbreak in Glasgow there was nothing to point to its origin from rats, since in 236 of these animals which were caught within the affected area not a single one then betrayed any evidence of disease, and of 124 from other parts of the city which were examined, the like was observed. Later, however, it was found to be present in those animals to the extent of about 2 per cent. of those caught. Certain observers have found the *bacillus pestis* in the bodies of fleas and ants which have been feeding on the bodies of diseased rats. In Tidswell's Report of the Sydney outbreak, organisms resembling *B. pestis* were found in fleas, which, when injected into the body of a pig, produced the bubonic form of disease; and Hankin discovered the bacillus in ants which had fed on the bodies of rats which had died of plague. Plague in man manifests itself in three typical forms, viz., the *bubonic*, *pneumonic*, and *septicæmic*. The first is characterised by enlargement of glands in different parts of the body, chiefly in the inguinal, axillary, and cervical regions. Boccaccio, in the Induction to his *Decamerone*, describes graphically the bubonic character of the plague in Florence in 1348. In this type of disease, swelling of a group of glands occurs on one or other side of the body, or one group on one side, and a second on the other side, and as a rule one of the group forms a distinct bubo. The swollen glands are extremely tender to pressure. The tissues above and around the bubo become brawny and œdematous, and as the swelling increases and suppuration advances the overlying skin becomes deeply congested and purplish in colour, until the bubo bursts usually from the 8th to the 10th day, whereupon a deep ulcerated surface is left with ragged, undermined edges. The temperature during the first two or three days rises, until it may reach 104° or 105° F., remaining at these points for two or more days longer, then it falls toward normal, only again to rise before the bubo bursts, when it again falls. Should however septicæmic infection

[1] *B. M. J.*, vol. i. 1900, pp. 1141, 1146.

supervene thereafter, it again rises, and remains high until death supervenes. The *pneumonic* form is always found more or less prevalent alongside of the bubonic type. It may be suspected to be present when during bubonic plague the number of deaths from pneumonia increases. The mode of onset, symptoms, and progress are generally those characteristic of pneumonia. Lobular pneumonia is the rule, not lobar, but its signs are not so fixed as in lobar pneumonia; in other words, a dull area to-day may in a day or two clear up, and a second new dull area may be found. The sputum, which after twenty-four hours is more or less blood-stained, contains enormous numbers of bacilli. This form is more fatal than the bubonic. The septicæmic form is less common than the others. Whether it is due to a mixed infection or not has not yet been determined. It would appear, however, that the glands of the body are more or less generally affected, but not to a sufficient degree to cause definite swellings. Death commonly supervenes early, due to the profound toxic effect upon the system. In the Glasgow outbreak the type was mainly bubonic, but individual cases of both pneumonic and septicæmic types were observed.

Symptoms.—The symptoms of onset observed in the Glasgow cases were severe headache, rigors, severe prostration, pain in back and limbs, and the bowels more often constipated than loose. The face of the patients was pale especially about the mouth, the expression was dull and heavy, and presented an anxious look. This last appearance became more marked when the patient was moved, doubtless owing to the pain induced in the glandular swellings, even when the patient appeared unconscious to his surroundings. The temperature rose quickly, and by the second day reached from 102° F. to 105° F. It was remittent in character, being usually one or two degrees lower in the morning. The pyrexia ended either by crisis or lysis. Crisis occurred in the untreated cases at periods varying between 5 and 18 days after illness began. Where secondary septicæmic infection occurred, the temperature continued high, as it did also in severe cases followed by early death. The amount of bubonic disturbance varied. In most of the cases the axillary and inguinal glands were simultaneously affected; in others, the enlargement was confined to one group of glands. In the milder cases resolution occurred without suppuration, but in the bulk of cases, a bubo went on to suppuration and ruptured, from which flowed a seropurulent, flaky, discharge. which in all the cases but one proved to be sterile, or free from *B. pestis.* In the exceptional case, virulent plague bacilli were obtained from the fluid discharged. Great tenderness on pressure of buboes was present. The skin of the patients was dry and hot; sweating was generally absent. No specific rash was observed, but mottling of the skin over trunk and thighs, more marked than the mottling of typhus but less than the mulberry eruption, was noticed. On its disappearance it left a dusky hue behind it. No petechiæ were found in the skin. The tongue was covered with a white fur and showed clean edges, but occasionally it exhibited a dorsal brown fur; the lips were dry, and sometimes covered with sordes. The respiration-ratio was notably increased, quite apart from any pulmonary complication. Pneumonia, however, was present as a

complication in a number of the cases, in the form of patches, and not in lobar areas. Delirium and coma were more or less present in all of the cases, but the former was usually slight and mildly delusional in type.

Some of the Glasgow cases were so slight that they might be named as of the type *pestis ambulans.* The buboes were small, so much so at times that needle-puncture for diagnostic purposes was difficult. The temperature was rarely above 100° F., and was usually under that figure; but notwithstanding the apparent lightness of the infection, proved by finding the bacillus in the glands, the patients presented a heavy, drowsy-looking expression of face, increase of pulse-respiration ratio, injected conjunctivæ, and a furred tongue. In the typical pneumonic case large numbers of *B. pestis* were found in the sputum. This patient recovered. The Report on the Glasgow outbreak by Dr. Chalmers, Medical Officer of Health, from which the foregoing details have been mainly obtained, contains a valuable original contribution by Cairns on the agglutinative property of blood serum in plague cases, which is well worthy of study.

Incubation Period.—The average period is from three to five days, but it has been asserted that it may be shorter, or that it may be longer.

Modes of Infection.—The bubonic form is believed to be due to the entrance of the *B. pestis* into broken cutaneous surfaces, such as from the bites of insects, or otherwise produced; and the pneumonic form to be due to the inhalation of dust containing the organism. Kitasato has found *B. pestis* in the dust, and Yersin, in the soil of houses occupied by plague-stricken cases.

Modes of Spread.—There can be little doubt that as a means of spreading the disease from one place to another the presence of the disease in rats is a most important factor. In this way plague may be transmitted in ships from port to port. Whether the fleas of rats are capable of conveying the disease to man is not yet clearly decided, but that they are able to transmit it from animal to animal has been demonstrated.

Preventive Measures.—Since evidence points so strongly to the existence of the disease in rats either previous to or contemporaneous with an outbreak in man, a vigorous crusade must be undertaken for the extermination of these rodents during the existence of an outbreak, or earlier if disease be observed in them. In the outbreak in China, it was found by Kitasato that in Kobé one rat in five, and in Osaka, one rat in ten was affected by plague. None of the rats killed in Glasgow in the infected area were found affected. Their extermination then may be accomplished by trapping and killing, and by cremating their bodies. Danysz of the Pasteur Institute, Paris, has proposed to attain this end by feeding them with cultures of a cocco-bacillus resembling in general characters the *B. coli.* The plan seems to have been successful in Paris, Lille, Hamburg, and other places, but it seems to have signally failed in Glasgow. Rats were fed with the serum, but none of them died, and of two which were inoculated with it only one died. Measures must also be taken to prevent its spread among human beings who have been exposed to infection. This may be attained by injecting a pro-

tective serum into the body. There are three such serums or vaccines, viz.: Haffkine's, Yersin's, and that of Roux. They all confer immunity, but the degree of protection varies. Haffkine's vaccine is made by heating cultures of *B. pestis* to 70° C. for one hour, the serums of Yersin and of Roux are obtained from the serum of the blood of a horse which has been rendered immune by injection of dead plague bacilli. For protective purposes Yersin's serum may be injected in amounts from 10 c.c. to 40 c.c., but for curative purposes in those suffering from the disease, the best effects are obtained from intravenous injections of doses from 40 c.c. to 100 c.c. In addition to such measures, all infected material should be burned, houses thoroughly disinfected, and bodies of persons who have died of the disease cremated, or otherwise satisfactorily disposed of.

Leprosy is a disease which has been known since the Mosaic dispensation, and probably, since earlier times even, not only with respect to its clinical features but also to its communicability. The bacillus was discovered by Armauer Hansen in 1873. It prevails to-day in both hemispheres in limited areas. In Europe, it is found in Norway, Sweden, Spain, Portugal, Italy, Greece, Russia (Southern), Turkey, and some of the islands of the Mediterranean. In Africa, in the Cape, Senegal, and other parts. In Asia, in India, notably in Colombo, Ceylon, and in China; in certain islands of the Pacific, as Hawaii and the Sandwich Islands; and in America, in Mexico, the West Indies, in New Brunswick, Louisiana, and other places. Although endemic in Great Britain up till the end of the seventeenth century, it has now disappeared except in cases imported from abroad. The disease chiefly invades the skin. It is due to a specific bacillus, attempts to cultivate which out of the human body having up till the present signally failed. It appears to require for its growth living human tissue. The *bacillus lepræ* measures from 5 to 6 micro-millimetres in length. It is stained with the ordinary stains, the methods of Ziehl-Neelsen and of Gram bringing out its characteristic features. The bacilli are found in abundance in the affected skin areas. The disease exhibits itself in one of two main forms, although both may be found in the same subject, viz.: the tubercular or nodulated form, and the anæsthetic form. The latter prevails largely in Africa and other tropical countries, the former being more common in Norway and other European centres. The disease seems to be uninfluenced by climate, since it is found in regions so remote as Iceland, Central Africa, and Honolulu, and while it is found largely on the seaboard, it obtains also in high inland places. Hutchinson believes it to be caused by eating partially cooked salt fish, but this view is not generally accepted; in fact, the intimate source of its origin is not known. It is contagious, however, not only among persons of the same nation, but to those of other nations. The case of Father Damien is a case in point. Its incubation period is probably the longest of all the infective diseases. In Arning's case in which he successfully inoculated the disease into the body of a convict, it proved to be about two years. Isolation of those affected seems to be the only measure of any value in arresting the spread of the disease, and this policy, as carried out in Norway and elsewhere, would appear to have been attended with

some measure of success. Treatment seems to have but little effect upon the progress of the disease. Carrasquilla's serum treatment is followed by improvement, the leprous ulcerations suppurate freely and heal rapidly, and ulcers previously anæsthetic become sensitive, but other observers have not found the improvement to be permanent.

Rabies or hydrophobia which is produced in man by direct inoculation from the bite of a rabid animal, is believed to be of microbic origin, although the specific organism has not yet been isolated. Its incubation period is variable; the disease has developed as soon as six weeks after the bite, but it has also been delayed much longer than that. According to certain observers, it prevails more in summer

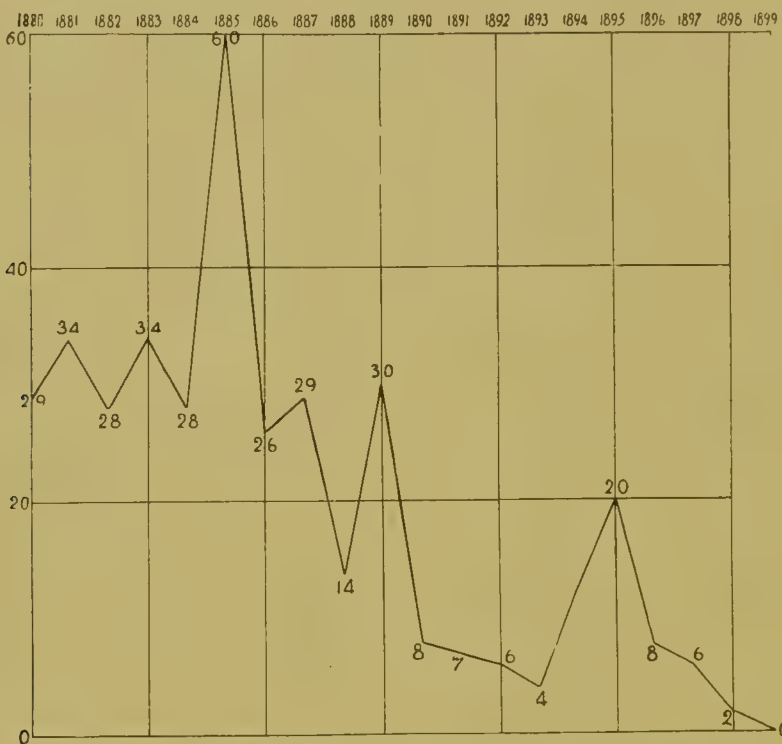


FIG. 218.—To illustrate Prevalence of Deaths from Rabies in England and Wales from 1880–1899 inclusive. The chart indicates the number of deaths for each year during that period.

and autumn than in winter. Of the deaths which have been recorded more have happened in the male than in the female sex, and between the ages of five and fifteen rather than over the latter age. The specific organism apparently has its seat in the nervous centres, and chiefly in the spinal cord, or the toxines to which it gives rise act most on these centres. Pasteur based his line of treatment on that fact. He found that when a rabbit was inoculated by putting under the dura mater a piece of the spinal cord of an animal or person who had died of rabies, the inoculated animal developed the disease. If the spinal cord of the rabbit were then taken and exposed in perfectly dry air, he found that it lost its virulency in direct ratio to the period of exposure. By using, therefore, cords of different rabic strengths, he was able to immunise dogs or human beings against the disease;

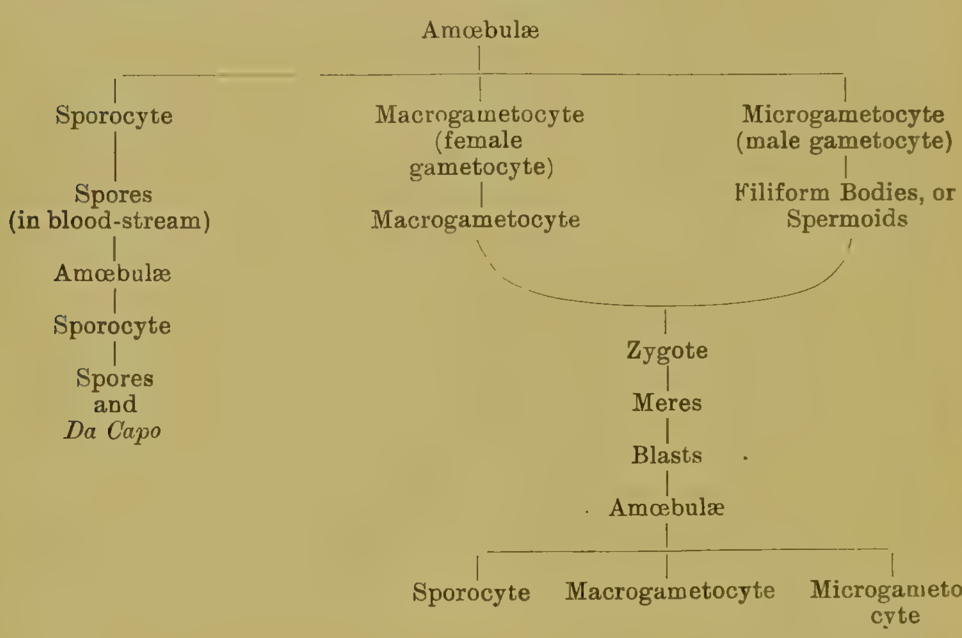
and in like manner, persons are treated who have been bitten by rabid animals. This treatment has proved very successful. The best preventive measure against the spread of the disease is the muzzling of dogs during the hottest months of summer, the destruction of all unowned dogs, and of those which exhibit suspicious symptoms. In 1892 the Board of Agriculture issued the Rabies Order, by which county authorities might set the above measures in operation. In 1897, however, the order was enforced. The preceding figure shows the number of deaths in England and Wales from rabies from 1880 to 1899 inclusive, and the effect of the compulsory muzzling of dogs since 1897.

Malaria. This polymorphic disease prevails very extensively throughout the world; indeed, it is known in both hemispheres, and in all continents. At the same time, it may be said to be limited in geographical distribution to a belt which runs round the globe between the fourth isothermal line north, and the sixteenth line south of the equator. Within the above area, its incidence depends upon the presence of rivers or stationary masses of water; thus it is found to be endemic around low-lying, marshy grounds, in river deltas, around lakes, and, indeed, wherever water is apt to lie upon the ground-surface. On the Continent of Europe, it prevails in France, in the valleys of the Loire, its tributaries, and in those of the Rhone; in Germany, in those of the Rhine, Elbe, and other rivers, and along the Baltic coast-line; in Russia, along the course of the Volga, and on the banks of the Caspian Sea. It is found in nearly every province of Holland, in some parts of Belgium, Switzerland, in Sweden around Lake Wener, in Austria along the banks of the Danube; around the Black Sea; extensively in Southern Italy, and around the whole coast of the Mediterranean. It affects Southern Asia, includes the East Indies, but seems to be less prevalent in Japan. It is found in Northern Australia, many of the islands of the Pacific, but does not prevail in New Zealand or Tasmania. It is very prevalent in America along the Atlantic seaboard, around the great Canadian Lakes, and in New England, and it operates most harmfully on the populations of Southern American States as Cuba, Mexico, and others. It is very virulent in all parts of Africa, except, perhaps, the extreme south. In England it used to prevail in the fen districts of Norfolk, Cambridge, Somerset, Kent, and others, and in Scotland in the Carse of Gowrie and the valleys and courses of the larger rivers. It does not appear to have ever been present to any extent in Ireland. It does not exist in endemic form in any part of Great Britain at the present day. Since the time of Hippocrates, who was familiar with its clinical characters, many theories as to its prime cause have been promulgated. Known to be intimately associated in some way with stagnant marshy waters, it was believed in some way to be due to conditions of soil. Later views, however, associated the cause with infusoria, poison secreted by marsh animalcules, cells of water-plants, etc., until in 1879 Klebs and Tommasi-Crudelli attributed it to a microbe, to which they gave the name of *b. malariæ.* In November 1880, Laveran a French surgeon in Algiers, when making microscopic examination of the blood of a soldier who was suffering from ague,

discovered the presence of bodies with which hitherto he was unacquainted. By further examination and observation he arrived at the opinion that these might be the cause of the disease. The significance of Laveran's corpuscles, however, was not appreciated at the time, nor indeed for some time afterwards. It was not till 1895 that further progress in the solution of the cause was made. Manson, doubtless prompted by his discovery of the propagation of Filariasis by means of the mosquito, suggested to Ross, an Indian army surgeon then about to proceed to India, a line of research in this direction. For two and a half years Ross examined many mosquitos without any reward, but at the end of this time at Sigur Ghat, near Ootacamund, he noted for the first time a mosquito which had spotted wings. Capturing eight of them, he set them to feed on the blood of a malarious patient, and at varying intervals of time thereafter he dissected their bodies and examined them microscopically. The first six showed negative results. In the seventh, however, he observed some unusual cells on the outer wall of the stomach, which contained granules of melanin—the black colouring matter of the blood; in the eighth, he found like cells in the same position, but larger. At this stage, however, his malarial investigations were terminated by reason of the outbreak of plague in other parts of India, and which required his services. During this time, however, in his spare moments, he worked at the life-history of similar organisms in the blood of birds. The following is a summary of Ross' discoveries in birds: When he fed mosquitos on the blood of birds containing this hæmatozoon—called by Labbé *halteridium*—he found in the stomachs of the insects the pigmented cellular bodies which he had seen in mosquitos that had been fed upon human malarial blood, but if the blood of birds contained no hæmatozoon, no such bodies were found in the mosquito. He noted the gradual development of those pigmented cellular bodies on the outer surface of the stomach-wall where they formed wart-like projections, to which he gave the name of *proteosoma-coccidia*,—but which may more properly be called *zygotes*,—until they matured and ruptured, throwing large numbers of small falciform bodies into the body-cavity of the insect. He further watched the progress of these bodies—called by him *germinal rods*—towards the veneno-salivary glands, ducts, and proboscis of the insect, and thus established the cycle of development of the avian parasite within the mosquito. The Italian observers, Grassi, Bastianelli, Bignami, Celli, Golgi, and others took up the work at this stage, and continued it. The combined observations of these men, of Koch, and many others have practically completed the life-history of the blood-parasites of malaria. While similar parasites attack birds, cattle, monkeys, and frogs, it is now well established that three different species of hæmatozoa live in the blood of man, corresponding to the three main forms of malarial fever, viz.: the tertian, quartan, and æstivo-autumnal or pernicious types. To the hæmatozoon of the first Ross has given the name, *Hæmamœba vivax*; to that of the second, *Hæmamœba malariæ*; and to that of the third, *Hæmomenas præcox*. These belong to the *Protozoa*, order *Sporozoa*, the characters of which are as follows, viz.: (1) they are parasites, and are represented by true cellular elements; (2) the cells consist of protoplasm, a nucleus, and a nucleolus or karyo-

soma; (3) the cells are true endocellular parasites or cytophages; (4) they possess a free amœboid phase of existence; (5) they multiply by spores. The Sporozoa embrace the following sub-orders: (*a*) *Microsporidia*, of which the corpuscles of Cornalia in silkworm disease may be taken as a type; (*b*) *Sarcosporidia*, of which Miescher's corpuscles found in the muscle of frog, sheep, pig, and ox are examples; and (*c*) *Coccidia*, which give rise to infections in rabbit, cat, mouse, ox, and man. In 1882, Pfeiffer found that in the development of the coccidium there was alternation of generation, a phase in one animal in which the parasite is endogenous and asporular, and another, in a second animal, in which it is exogenous and sporular. In 1887, Metschnikoff affirmed the view that the malarial parasite was related to the coccidium. The life-history of the malarial parasites is as follows: the organism—an amœba—called an *amœbula*, enters a human red blood corpuscle, begins to grow rapidly at the expense of the corpuscular contents, and assimilates the hæmoglobin which it converts into *melanin*, until it finally monopolises the corpuscular body. At this stage one of two things happens, viz.: either the amœbulæ become *gametocytes*, that is, uniting cells, or they become *sporocytes*, or spore-bearing cells. In the latter case, the nucleus of the amœbula subdivides into a number of smaller nuclei round each of which protoplasm forms, each to become a spore. When this process is complete, the corpuscular wall ruptures, and the spores and melanin granules are shed into the blood-stream, the former to re-attack fresh corpuscles as amœbulæ, the latter to be absorbed by the leucocytes, and to be borne to such internal organs as spleen, liver, brain, etc., where the pigment is deposited. In this way the process goes on repeating itself. It was not until 1885 that Golgi—an Italian observer—described this phenomenon of sporulation, showed that the spore-distribution in the blood-stream was contemporaneous with the attacks of fever, and further pointed out that at this stage the exhibition of quinine was likely to be most effective. In the tertian type—usually the most common—the *H. vivax* passes through the above stages in man in 48 hours, and thus the outbreaks of fever appear every second day, or the third day if the day of the former attack is reckoned as the first; in the quartan type, the parasite sporulates in 72 hours, the attack recurs every third day, or fourth day if reckoned as above. It sometimes happens, however, that two crops of parasites in the tertian type come to maturity on alternate days, hence the attack occurs daily, and is then designated as quotidian fever. In the æstivo-autumnal or pernicious type, the symptoms are markedly different from the others, and do not exhibit the same periodicity—although the parasite matures every 48 hours. The foregoing, therefore, represents the endogenous phase of existence of the malarial parasite. The other form of cell is the *gametocyte*. If such cells be removed in the blood corpuscles from a patient and placed on a warmed slide, it may be observed that certain of them throw off filiform bodies. This phenomenon, however, does not take place within the body of man. In 1897, M'Callum of Baltimore showed from his investigations that there were two kinds of gametocytes, viz., (*a*) those which produced the filiform bodies—the male gametocytes, or *microgametocytes*,—and (*b*) those which do not

undergo any such change—the female gametocytes, or *macrogametocytes*. As soon as malarious blood is sucked into the stomach of the mosquito, the microgametocyte bursts, the filiform bodies or spermoids are liberated, enter the macrogametocytes and fertilise them, and from the union new bodies are formed which individually are called a *zygote*. In the stomach of the mosquito then, the zygote travels to the walls of the organ, pierces the inner coats, and as soon as it reaches the muscular coat begins to grow, so that at about the end of a week it is about 500 times its original size. If the zygote be now microscopically examined, it will be found divided up into eight or ten actiniform bodies called *meres*, from the periphery of which a large number of filiform bodies or *blasts* are formed. As the zygote matures, it increases in size, until it finally bursts and its contents are thrown off into the body-cavity of the insect—that is, into the space between the stomach-wall and the body-wall. These blasts make their way—whether by their own motile power or not is not yet known—into the cells of the veneno-salivary glands, thence into the salivary ducts, then into the biting parts of the insect, so that when the insect bites a human being they enter into the blood-stream. The following diagram shows the two phases of the life-history of the parasite.



It next remained to discover whether all mosquitos were capable of acting as definitive host to the malarial parasites. To this point much research has been given, and so far as has been ascertained, it seems well established that only certain insects of the genera *Anopheles* and *Culicidæ* are so capable, and that if the malarial parasites are taken into the bodies of other insects of these classes, they are either digested or are disintegrated, as they certainly do not undergo development. The insects of the genus *Anopheles* which have been proved to act as definite hosts of the human parasite are the *Anopheles maculipennis*, which is called by the Italians *A. claviger*

(Fabricius), by Americans *A. quadrimaculatus*, and in Africa the *Anopheles funestus*.[1] The descriptive names of the first three owe their origin to the presence of four dark spots upon the wings, which are most conspicuous in the female insect. *Culex pipiens* of the genus *Culicidæ* is the insect by which, so far as is known, the parasite of birds is transmitted and matured. Experiments have demonstrated that this insect fails to carry the human parasite, and *A. maculipennis*, the avian parasite.

In order to demonstrate the correctness of the above views, observers have submitted themselves to experiments. Insects which were fed on the blood of a person suffering from pure benign tertian ague in Rome were transmitted under suitable precautions to London, and were there suffered to bite and feed upon the blood of persons free of malarial infection, with the result that the persons experimented upon were attacked by the same disease, as proved not only by the clinical symptoms, but by the discovery of the parasite in their blood.[2] Fearnside of the Indian Medical Service suffered himself to be bitten by mosquitos which were fed on the blood of a person known to be affected with spring tertian fever, and was seized with the disease in due course, the hæmamœbæ being found in his blood.[3]

Prevention of Malaria.—This can only be attained by the adoption of various preventive measures, which are included in the following, viz.: (1) Attack upon the breeding-grounds of the mosquitos involved; (2) The use of mosquito-proof dwellings; (3) The liberal preventive and curative use of quinine.

I. *Attack upon Mosquito Breeding-grounds.*—The *Anopheles maculipennis* and *Culex pipiens* deposit their eggs in water which is either slightly moving or is stagnant. The former prefers clear moving water. The latter is not so particular, as any stagnant puddle of water or water retained in vessels will suffice. The first remedy must, therefore, consist in deep-draining and cultivation of marshy lands, so that surface water may be prevented from collecting and may be enabled to pass away by the underground drains. It is probably for this reason chiefly, that malaria has ceased to be an endemic disease in Britain. In the smaller towns and villages of malarious districts attention must also first be paid to surface drainage, and water must not be allowed to remain in vessels during the mosquito breeding season for so long a time as will enable the eggs to develop through the larval and pupa stages into the complete insect. Obviously, however, this measure can only be limitedly applied, as it would be impossible to drain the borders of marshy lakes, and it would put an end to the rice-growing industry. In such cases, and even also where surface water is conveyed by artificially-constructed channels to a river, some other measure of destruction of eggs and larvæ must be instituted, as for example the introduction of such fishes as feed upon stream larvæ and insects, or the addition to the water of such substances as will destroy the larvæ. From the experiments of Celli and Casagrandi it is evident that substances which act destructively upon the larvæ operate in one of two ways, viz.: either

[1] *B. M. J.*, vol. i. 1901, p. 193. [2] Ibid., vol. ii. 1900, p. 949.
[3] *Indian Med. Gazette*, 1901.

by rendering the water sufficiently poisonous, or by preventing the larvæ from breathing. During the larval state both *A. maculipennis* and *C. pipiens* breathe by means of breathing organs which are projected just above the water-level; therefore it has been proposed to put in the water an oily substance such as petroleum, which by forming a film on the water-surface prevents their respiratory action. These observers have found this latter method efficacious when the petroleum was present in the proportion of 1 cubic centimetre to 1000 cubic metres of water-surface. This is probably the cheapest mode of destroying the larvæ, and it has proved effectual in many practical trials. Certain of the anilin dyes mixed with the water are also very destructive upon larvæ; and of these *gallol* and *malachite green* have been found efficient, the former in the proportion of 0·0062 per cent., and the latter, of 0·0125 per cent.

II. *The Use of Mosquito-proof Dwellings.*—Experiments in the Campagna with a mosquito-proof hut showed that persons might live with impunity in the most malarious districts, provided that they took the precaution not to be out-of-doors after sunset or before sunrise. This remedial measure can, however, have but a very limited application. It is, at the same time, one worthy of practice by Europeans who are compelled temporarily or permanently to live in malarious regions. Another important precaution is where on expeditions tents have to be put up, that these should be erected at least 600 to 800 yards from native quarters. This is suggested because it has been found that mosquitos take refuge during the day in the darkened corners of these huts, and because experience has shown that the average mosquito flight does not extend that distance and that even in windy weather, when the insects might be blown for longer distances, they commonly seek shelter and thus do not reach the tents.

III. *The Use of Quinine.*—As a preventive measure quinine should be taken periodically. As a curative measure, its use is most effective during the paroxysms of fever, since, as has been pointed out, it is then that spores are liberated from the sporocytes into the blood.

Glanders is mainly a disease of horses, asses, and mules. When it appears in a stud it quickly spreads, and the affected animals must according to law be destroyed. It is communicable from animal to man both by contagion and by direct inoculation. When the disease attacks man it ordinarily ends fatally, as in the case of Dr. Hoffmann of Vienna in 1889. Its causal factor is the *B. mallei*, which is a rod-shaped organism, one end of which is more thickened or clubbed than the other, and which is non-motile and non-sporular. It does not take the stain by Gram's method, but stains well with Löffler's methylene blue or with carbol-methylène-blue. The organisms are found in the discharges from the nose of the affected animal, in the small grey bodies which are found in the respiratory passages, and in the ulcerated bronchial mucous membrane; or in the nodules in the skin and subcutaneous tissue known in veterinary practice as farcy buds.

Anthrax or Splenic Fever of cattle, sheep, goats, pigs, deer, horses,

and other animals, and wool-workers' disease, or malignant pustule —its synonyms in man—is a very fatal disease. In man, its constitutional or pulmonary form, which is known as wool-sorters' disease and was first recognised in England in 1879, is usually induced by inhalation of spores of the bacillus, and mainly affects the lungs. Malignant pustule is an external local manifestation of the disease due to direct inoculation of a wounded point with the specific micro-organism. The first published account of malignant pustule in England is dated 1863, although it was known before this time. It appears to be endemic in Cyprus due to the sting of the insect Sphalangi. It is a disease, therefore, which is communicable from animals to man. The disease was well known in animals before its communicability to man was dreamt of. Its connection with man was first discovered when an investigation was made by Dr. Bell of Bradford into a strange disease which broke out among wool-sorters in that town. It has also been seen many times among hair-sorters since. Workers among hides and hoofs are liable to be attacked with the external form of the disease, if the materials have been taken from diseased animals. The pustule or boil which forms by inoculation on the skin begins at first as a small inflamed vesicle or pustule, which becomes black, and is surrounded by a thickened brawny area of tissue from which pass inflamed lymphatic vessels. It may end in resolution, or the central black necrosed tissue may slough out with suppuration with but little accompanying constitutional mischief, or on the other hand, the pustule may be the source of profound constitutional disturbance.[1]

Of 1077 cases collected by Koch, in 490 the pustule occurred on head and face, 45 on neck, 370 in the upper limbs, and in the remaining cases on other parts of the body.[2] The disease is caused by the *B. anthracis*, a rod-shaped organism, which varies from 2 to 10 micro-millimetres in length, and from 1 to 1·5 in breadth. It stains freely by Gram's method. It is non-motile, sporulates freely, and its spores are among the most resistant to destructive agents. All parts of an infected animal carry organisms, hence blood-smeared hides, hair, or hoofs, when dry, convey the disease. The dust contains the spores. During life, it is conveyed from animal to animal by direct or indirect contagion, by the association of the infected and non-infected, and also by infected public watering-troughs. The disease is believed also to have been conveyed by infected oats and oil-cake. In the Queen's Bench Division, judgment was given for a defendant who resisted payment of a bill for oats supplied to him, on the ground that the oats had caused an outbreak of anthrax among his horses. The jury awarded him damages for the horses which had died.[3] In another case, it was proved that the disease had been transmitted to oxen by means of oil-cake. In wool-sorting and hair-sorting factories precautions must be taken to protect the employées, either by steeping in disinfecting solution the materials to be handled, or by instituting bench ventilators to carry away dust, and by providing muzzles which are to be worn by the workmen. In 1899 the Board of Agriculture issued the Anthrax Order for England, under which

1 *B. M. J.*, vol. ii. 1901. p. 133, *et seq.* 2 Treves's "Surgery," vol. i. p. 313.
3 *The Lancet*, vol. ii. 1895, p. 1517.

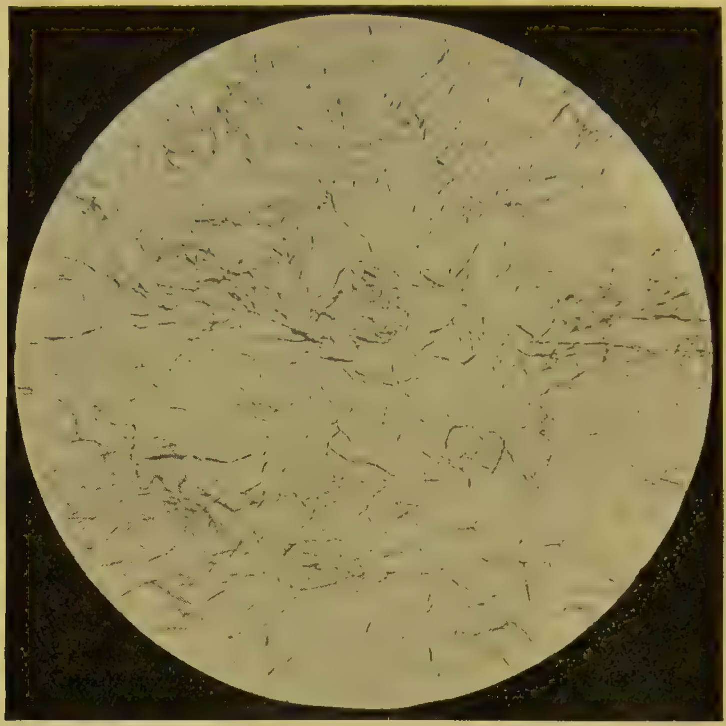


FIG. 219.—Photo-micrograph of pure culture of *B. Anthracis*. × 600 diameters. (Author.)

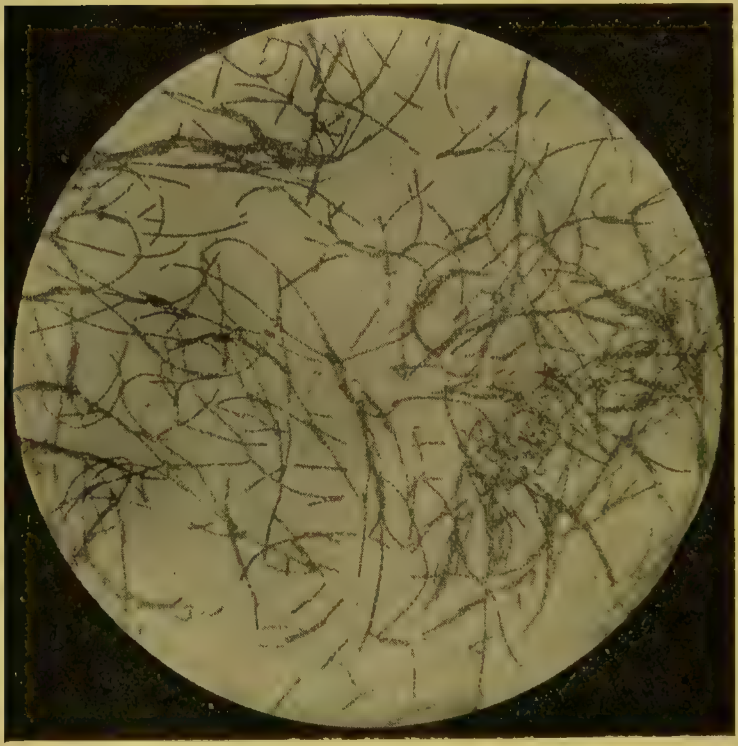


FIG. 220.—Photo-micrograph of pure culture of *B. Anthracis*. ×1200 diameters. (Author.)

cases of this disease in animals are dealt with, the owner being compelled to report their existence to the inspector, who in turn must inform the Medical Officer of Health.

Tuberculosis is a disease common to man and many of the lower animals which is produced by the *B. tuberculosis.* The organism measures on the average about 2·5 micro-millimetres in length, about ·2 to ·3 in breadth, and in form is slender and slightly curved. In cultures the bacilli are often shorter and thicker than those seen in phthisical sputum. They sometimes exhibit a well-marked beady appearance. In older cultures one end may appear clubbed, or branched, which latter appearance is not infrequently seen in avian tubercle. It is believed by certain observers that this bacillus is but one form of a pleomorphic mould related to actinomyces, and is not a

FIG. 221 illustrates the Geographical Distribution of Phthisis in the World. By the lightness or darkness of the hatching is the measure of intensity of the disease indicated. (*Vide* Ransome's Milroy Lectures.)

true bacterium. The organism in sputum stains well, however, by Ziehl-Neelsen's method; that is, with carbol-fuchsin first, which stains the bacilli red, then with Löffler's methylene blue, which stains the sputum itself blue. Whether the bacillus is spore-bearing or not is still an open question.

Phthisis pulmonalis may be considered to be a contagious, and an infectious disease. In cases where contagion has been proved, two conditions have been found to prevail, viz., insanitary environment and propinquity of persons, as in the relationships of husband and wife, sisters, or brothers, who occupy the same beds. The old doctrine of hereditary transmission must be put aside, but while the disease itself is not transmissible, its predisposition is. Pulmonary phthisis must largely have its origin in dried tubercular sputum, which, inhaled by susceptible persons, finds in them a suitable breeding-ground. The bacillus is found in enormous numbers in the sputum of those suffering from advanced phthisis.

Tubercular disease presents itself in the human subject in other forms than the pulmonary; for example as *tabes mesenterica*, and *tubercular meningitis*. The source of infection in the former class of cases is believed to be tuberculous milk. This is not impossible, since the milk of cows suffering from tuberculous udders contains bacilli in abundance. Another possible source of the disease in young persons and adults is the ingestion of imperfectly-cooked tuberculous meat. Opinion is much divided on this point. Some are of opinion that limited tubercular lesions present in the body of an animal render its flesh wholly unfit as human food; others, that if the limited lesions be extirpated the rest of the carcase may be safely used. The former view was expressed by the Congress on Tuberculosis held in Paris, the latter by the Victorian Commission and by the Royal Commission on Tuberculosis of 1898 in its Report. By reason of this difference in expert opinion, the policy of sanitary authorities on this point has been divided. In Berlin a middle course is adopted. By a Ministerial Decree of 1892, it was enacted that when the carcase of an animal exhibited general tubercular affection the whole carcase was to be condemned; where, however, one organ only, or two organs lying contiguous in the same bodily cavity were affected, the carcase was not to be deemed unfit for human food, but to be considered as flesh defective in quality. It was then thoroughly cooked under police supervision and sold at a reduced price. Such a course is at once reasonable and safe from all points of view.

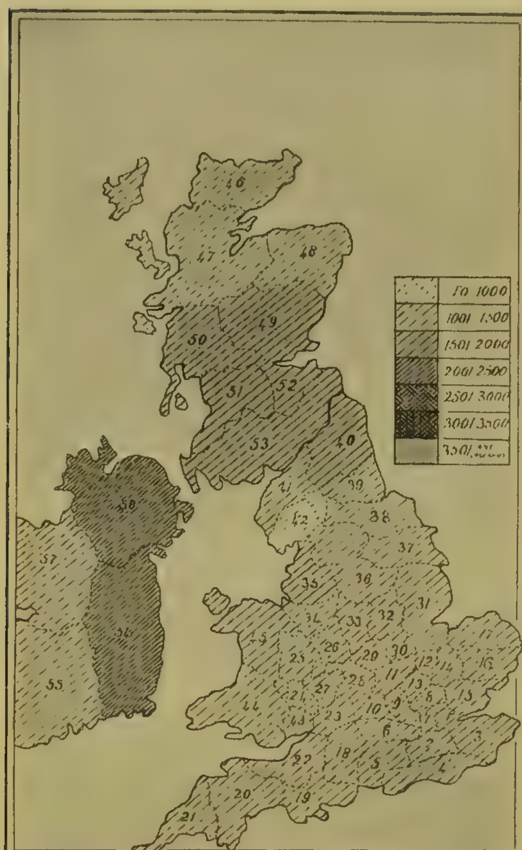


FIG. 222.—To illustrate the relative incidence and prevalence of Tuberculosis in Great Britain and Ireland. By reference to the Key the number of deaths per million of population living may be ascertained.

The following are the Recommendations of the Royal Commission on Tuberculosis, 1898:—

"C.—TUBERCULOSIS IN ANIMALS INTENDED FOR FOOD.

"6. We recommend that the Local Government Board be empowered to issue instructions from time to time for the guidance of Meat Inspectors, prescribing the degree of tubercular disease which, in the opinion of the Board, should cause a carcase, or part thereof, to be seized.

"Pending the issue of such instructions, we are of opinion that the following principles should be observed in the inspection of tuberculous carcases of cattle:—

"(*a*) When there is miliary tuberculosis of both lungs "(*b*) When tuberculous lesions are present on the pleura and peritoneum . . . . . "(*c*) When tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles . . "(*d*) When tuberculous lesions exist in any part of an emaciated carcase	The entire carcase and all the organs may be seized.
"(*a*) When the lesions are confined to the lungs and the thoracic lymphatic glands . . . "(*b*) When the lesions are confined to the liver . . "(*c*) When the lesions are confined to the pharyngeal lymphatic glands . . . . "(*d*) When the lesions are confined to any combination of the foregoing, but are collectively small in extent	The carcase, if otherwise healthy, shall not be condemned, but every part of it containing tuberculous lesions shall be seized.

"In view of the greater tendency to generalisation of tuberculosis in the pig, we consider that the presence of tubercular deposit in any degree should involve seizure of the whole carcase and of the organs.

"In respect of foreign dead meat, seizure shall ensue in every case where the pleuræ have been 'stripped.'"

Since it is the commonly accepted opinion that the propagation of tubercular disease among infants and young children is to be largely attributed to tuberculosed milk, precautionary measures must be adopted to prevent the sale of such milk. It is notorious that cows confined to sheds in towns and cities are highly tuberculous. Various factors contribute to this, more especially perhaps, want of an open-air life and the existence of insanitary environment. Hence the necessity for such constant and careful supervision of cows in town cowsheds by sanitary authorities as is prevalent in certain cities of Denmark and elsewhere. In the Dairies, Cowsheds, and Milkshops Order, 1899, issued by the Local Government Board of Scotland, article 15 of the Order of 1885, which stated that "if at any time disease exists among cattle in a dairy or cowshed or other building or place, the milk of a diseased cow therein (1) shall not be mixed with other milk; (2) shall not be sold or used for human food; and (3) shall not be sold or used for food of swine or other animals unless and until it has been boiled" was changed so that the word "disease" therein should be held to include such disease of the udder of a cow as is certified to be tuberculous by a veterinary surgeon. The Board drew the attention of local authorities to the recommendations of the Commission on Tuberculosis respecting cowsheds, in framing Dairy Regulations under the Order of 1899. The conditions laid down by the Commission for attached cowsheds in a populous place as entitling to registration of a dairy, are as follows, viz.: (1) an impervious floor; (2) a sufficient supply of water for flushing purposes; (3) proper drainage; (4) a depôt for manure at a sufficient distance from the byres; (5) a minimum cubic space of from 600 to 800 feet for each adult beast, varying according to the average weight of the animals; (6) a minimum floor-space of 50 feet for each adult beast; and (7) sufficient light and ventilation. Such regulations as the foregoing are intended to maintain average healthy

surroundings for healthy animals. But if tuberculosis in cattle is to be abolished, steps must be taken prior to this to apply such tests as will weed out animals already affected. For the purposes of public safety, probably it would be enough to secure that no animal with a tuberculous udder should be permitted to give milk to be used for human food. Local Authorities, as Manchester, seek however to prevent the sale of tuberculous milk by submitting samples to bacteriological examination. Delèpine has given a Table which illustrates the incidence of the tubercle bacillus in milk-supplies.[1]

TABLE XIX.

Source of Milk.	No. of Samples Examined.	No. found Tuberculous.	Percentage of Tuberculous Samples.
A.—*Mixed Milk*, from town or country dairies, collected at the farms, at railway stations, or in town dairies	693	79	11·37
B.—*Unmixed Milk*, obtained direct—			
1. From healthy cows . .	18	...	...
2. From cows diseased, or not stated to be healthy .	178	31	17·36[2]
	889	110	...

Considerable impetus has recently been given to the repression and prevention of tuberculosis by international conferences and congresses which are calculated to awaken the nations against the most fatal endemic scourge of modern times. Among the principal of these congresses was that held in London in July 1901. At that Congress, which has been rendered famous because of the unexpected and startling pronouncement in the address of Koch that human tuberculosis differs from bovine and cannot be transmitted to cattle, that human susceptibility to bovine tubercle is exceedingly slight, and that if such susceptibility does exist the infection of human beings is "but of very rare occurrence," several other prominent Continental sanitarians played prominent parts, and, notably in the address of Brouardel of Paris, showed what steps were being taken in their respective countries towards the stamping out of human tubercular disease. From the institution, moreover, of a British Association for the Prevention of Tuberculosis with branch Associations in the various important populous centres of the kingdom, some amelioration of this very prevalent and polymorphic disease may be expected. But this can only be achieved after many years of persistent, patient, and painstaking labour, not only on the part of the Association, but of Local Authorities, urban and rural, and of the population itself, on

[1] *Trans. Roy. Inst. Pub. Health*, 1901, p. 234.

[2] In this group is included the milk of over 100 cows in which the udder was found on veterinary inspection to be diseased. From 25 to 29 per cent. of the samples from these cows produced tuberculosis in guinea-pigs. M'Fayden and Rowland found tubercle bacilli in 22 per cent. of the samples which they examined.

advocated. Voluntary notification already exists in several populous centres. Compulsory notification is established by law in Norway, Spain, and other countries. There is much to be said in its favour, and there are equally strong objections to its practical use. It is however the only logical issue, whatever views may be entertained as to its expediency. The desiccated expectoration of phthisical persons being, doubtless, an important factor in the genesis of the disease, attempts have been made in various countries to compel the cessation of indiscriminate expectoration in public places, and the disinfection of tuberculous sputum.

The experiments of Cornet of Berlin with respect to the dust of rooms and hospital wards occupied by phthisical patients, and of Prausnitz and Petri with

FIG. 223.—Map showing relative prevalence of Tuberculosis in certain European countries and in Asia. Capital letters in Figure signify the initial letters of the capital cities. The various shadings, when compared with the shaded key, indicate the number of deaths per million of population in the respective countries. It will be noted that no returns are given for Spain (except the city of Madrid), Turkey, Greece, Portugal, and the Danubian States. (*Vide* City of Edinburgh Report on Prevention of Consumption.)

respect to the dust of railway carriages, amply prove the presence of *B. tuberculosis* and other micro-organisms therein. Of ninety-one animals inoculated by Petri with the sputum found in railway carriages twenty-eight succumbed to diseases produced by the inoculated material. In the bodies were found different pathogenic organisms, such as *S. pyogenes aureus* and *albus*, *Streptococcus pyogenes*, *Eberth's bacillus* of *pseudo-tubercle*, and the *bacillus* of *mouse septicæmia*. Of the other sixty-three animals, which were killed at the end of six weeks after inoculation, three were suffering from tuberculosis.

But many obvious difficulties emerge in the accomplishment of the above desiderata. In Germany, France, and America, and in certain of our own cities, public attention has been called to the public danger from tubercular sputum, and instructions have been printed and distributed broadcast in order to educate the public. The chief points embodied in these leaflets are : (1) that the infective matter

of the consumptive person is chiefly located in the sputum; (2) that it is only capable of doing harm when the sputum becomes dried, because then it is liable to become air-borne; (3) that, therefore, the sputum should be collected on pieces of paper, old cotton, or linen, and burned, and when phthisical persons walk abroad, that the sputum should be received into pocket spittoons, the contents of which may be washed into a drain, or better, should be consigned to the fire; (4) that when phthisis commences, the patient should be warned not to swallow the expectoration; (5) that the consumptive patient should sleep alone in a room occupied by himself only; and (6) in the event of death occurring from the disease, that the room and contents should be disinfected.

The establishment of sanatoria for the open-air treatment of incipient cases of phthisis has been strongly advocated by reason of

FIG. 224.—This Map graphically represents the relative prevalence and incidence of Inflammatory Diseases of the Lungs, excluding Phthisis, in different countries of the Old World, estimated as deaths per million of population. (*Vide* City of Edinburgh Report on Tuberculosis, 1900.)

the fact that in the early stages of the disease it is curable. Pathological examination of bodies has demonstrated the frequent existence of cicatrices of healed cavities caused by the disease. Such establishments, situated at high altitudes in dry air, unmistakably produce improvement and cure in suitable cases, but it must not be supposed that like good effects will follow in advanced cases, because in these mixed infection has probably occurred.

That all such measures as the foregoing are necessary is indicated by the fact that of all the zymotic diseases phthisis has shown least tendency to diminution from general sanitary measures. It is near the mark to say that one-seventh of the total annual deaths in the world is due to tubercular disease.

Naismith has collated the mortality returns for Scotland from tubercular diseases from 1855 to 1894, in the following Table.[1]

[1] *Trans. San. Ass. of Scot.*, 1896–97, p. 52.

TABLE XX.

Years.	Number of Deaths.
1855–1864	105,275
1865–1874	120,193
1875–1884	118,286
1885–1894	100,671

In 40 years therefore, in Scotland alone, nearly half a million deaths have been caused by the tubercle bacillus. During the last forty years, however, the death-rate from pulmonary phthisis in England has fallen by two-thirds, and in Scotland by more than a half, compared with former rates. It is likely, indeed, that such measures as the foregoing, in addition to increased numbers of open spaces in our cities, closer attention to ventilation of occupied rooms and workshops, greater insistence on smoke consumption, street cleansing, and scavenging generally, rigorous periodic examination of milch cows, and systematic meat-inspection, will produce a lowered mortality from tubercular diseases; but so long as crowded, imperfectly lighted, badly-ventilated houses exist, the disease will more or less prevail.

Pulmonary tubercle is confined to no country and to no hemisphere. (*Vide* Figs. 221, 222, and 223.) It has been held by some that its prevalence is in some way due to the measure of amount of moisture in the soil, but it is doubtful if this can be stated as a general principle. The potent factors in its production are not so much existent in the soil or in altitude, as in the intimate home-life of the people and the conditions of their environment, and to some extent also of their employment. Consanguinity is an important factor in its spread in respect that it produces a type of constitution ill-fitted to resist the invasion of the bacillus. Davies[1] has established this with reference to the Manx population. Over a period of fifteen years the average annual death-rate from phthisis in the Isle of Man was 25·7 per 10,000 living, or about double the rate for England and Wales.

[1] *B. M. J.*, vol. ii. 1900, p. 904.

CHAPTER X.

CHARACTERISTICS OF INFECTIVE SUBSTANCES OF ZYMOTIC DISEASES.

As has already been indicated, the infective agency in zymotic diseases is the organism or its spores. Zymotic diseases differ as to their degree of infectivity. Each disease has what may be termed its striking distance, that is, the area around the infected person within which the infective material will take effect upon a susceptible person. Some diseases have long, others short, and others, intermediate striking distances. Small-pox is a typical example of the first. This has been fully proved with respect to small-pox hospitals and neighbouring populations. For this reason, the English Local Government Board has advised that a local authority should not contemplate the erection of a small-pox hospital on any site where, within a quarter of a mile of it as a centre, there is a hospital or other like establishment, or a population of 150 to 200 persons, or within half a mile of it a population of 500 to 600 persons. Typhus fever affords a good example of the second. Whatever the nature of the infective agency, it appears to be rapidly destroyed or neutralised by abundance of air, for the infective zone is confined to the immediate vicinity of the affected person. The factor which seems largely to determine the area of infectivity in all zymotic diseases is the mode or channel by which the infective material is shed from the body. In many diseases as erysipelas, scarlet fever, measles, and some others, it is thrown off not only in the bodily secretions, but also in the exfoliated scurf-skin, and thus it may be carried for considerable distances by the air or upon objects. In diphtheria it does not spread far from the body of the patient, being discharged mainly in the moist mucous throat secretions. Too much has been made of the absence of the specific micro-organisms from the expired air of those suffering from zymotic diseases. The experiments of Kœniger and others amply demonstrate that the mere act of speaking discharges micro-organisms into the surroundings of the patient, as do also the acts of coughing and sneezing. Therefore in those zymotic diseases in which the organism has its natural habitat in the air-passages or lungs, it must be held that organisms are discharged by such acts as those named to render infective the air around the patient. In enteric fever and cholera the infective matter is mainly thrown off in the intestinal discharges, hence so long as these are in a moist condition the infective matter is little likely to become air-borne ; so soon however as the discharges become dry, air-borne infection becomes possible. It is for this reason that experience has demonstrated the non-contagious character of these diseases.

All infective diseases pass through three stages, viz.: *Incubation, Invasion, Infectivity*. These are arbitrary terms, however, and by no means indicate sequential conditions, since in certain diseases infectivity is contemporaneous with incubation and invasion. The duration of these periods differs in different diseases. Cholera has probably the shortest, and leprosy and rabies, the longest incubation periods. Infectivity may be said to be existent in any case from the time the specific organism multiplies in the body until it ceases to exist. While, for example, in diphtheria a patient may have apparently recovered from an attack, the bacillus may be found for varyingly long periods thereafter in the nasal or throat secretions, and in enteric fever, in the urine long after the establishment of apparent recovery. Incubation may be defined as that period which comes between the growth of the specific organism in the body and the production of fever, the latter being the indication of its multiplication and toxic effect. It may be divided into two stages, viz., the *latent* stage, during which the existence of the organism in the body is not detectable by clinical symptoms; and the *invasive* stage, during which clinical symptoms indicate bodily attack by the organism. The former has to do with the growth of the organism itself, the latter, with the effects of the growth of the organism upon the body. Incubation periods vary in duration in different diseases.

TABLE XXI.

Short Incubation Periods (1 *to* 6 *days*).

Anthrax (in man)	1–1½ days
Cholera	1–3 ,,
Diphtheria	2–5 ,,
Erysipelas	1–4 ,,
Glanders (in man)	1–4 ,,
Influenza	1–6 ,,
Foot-and-mouth disease	3–5 ,,
Puerperal fever	3–5 ,,
Scarlet fever	2–4 ,,
Relapsing fever	about 5 ,,
Plague	3–6 ,,

Long Incubation Periods (7 *to* 21 *days*).

Whooping-cough	7–14 days
Typhus fever	7–14 ,,
Small-pox	10–15 ,,
Chicken-pox	10–15 ,,
Rabies (in animals)	6–24 ,,
,, (in man)	6 weeks to 2 years
Enteric fever	12–20 days
Measles	8–12 ,,
Rötheln	10–14 ,,
Mumps	14–21 ,,
Yellow fever	2–10 ,,

Variable Incubation Periods.

Malaria	6–20 days
Tuberculosis	very variable—usually long
Tetanus	,, ,, within 10 days

Invasion is the period between the intervention of the febrile symptoms and the appearance of the rash—where a skin eruption is a usual phenomenon. In scarlet fever, it is from one to two days; in small-pox and typhus fever, from two to three days; and in measles, from three to five days.

Infectivity is the period during which the infected person discharges from his body infective material. Its duration is limited to some extent by the intensity of the attack and the time which elapses before complete restoration to health. It only ceases when infective material ceases to exist in or to be discharged from the body. While a period of forty days may be held to cover the period in the majority of zymotic diseases, it must be held subject to modification. In view, for example, of the liability of "return" cases of scarlet fever where this period of isolation has been observed, the period of isolation or infectivity has been extended to eight weeks.

The infective period may be reckoned to last in the following diseases, as follows:—

In cholera,—during the whole period of discharges, and for a week thereafter;
In small-pox and chicken-pox,—during the whole illness till after the last particle of the last crust has fallen from the body, and for ten days thereafter;
In scarlet fever,—during the whole illness until all exfoliated epidermis has been shed—eight weeks; or longer, if ear or throat sequelæ exist;
In measles and Rötheln,—during incubation period, through febrile and eruptive stages, until all epidermis has been shed — twenty-one to twenty-eight days;
In whooping-cough,—during the whole period of attack, even before "whooping" occurs—six to eight weeks;
In mumps,—during whole illness, till ten days after parotitis has disappeared—not less than twenty-eight days;
In enteric fever,—during whole illness, until complete restoration to health;
In diphtheria,—during whole illness, till ten days after bacillus has disappeared from throat and nasal secretions—four to six weeks;
In erysipelas,—from beginning of inflammation of skin till ten days after peeling of skin has ceased—three to four weeks;
In plague,—during whole illness, until complete restoration of health—a variable period.

Exposure to infection implies the possibility of attack, and consequently, the question—How soon after such exposure may a child who has not previously had the disease be permitted to return to school?—is of considerable importance with reference to prevention. The English Medical Officers of Schools Association has established a code of regulations bearing on this question, the substance of which is as follows: After thorough disinfection of person and clothing, the child may be permitted to return to school; in the case of diphtheria, after 12 days; in measles, after 16; in German measles, 16; in small-pox and chicken-pox, 18; in scarlet fever, 14; in whooping-cough, 21; and in mumps, 24 days: after exposure to infection.

Modes of Spread of Infective Diseases.—The liability to attack by zymotic diseases is determined by exposure to the area of infection, either from an infective person or from infective material, and by predisposition, susceptibility, or vulnerability. The power of a zymotic disease to spread depends upon the character of the infective material

and its capacity to live outside of the living body; for example, while tetanus is a microbic disease—the *B. tetani* being anaerobic—the disease cannot be conveyed from person to person by the air. Again, those infective materials which quickly succumb to fresh air and sunlight are limited as to area of infectivity, while on the other hand those which are more resistant and are capable of sustaining an existence in media outside of the body, as in soil, food, water, sewage, etc., have therefore a larger field of infectivity. The modes by which infection may be transmitted are as follow: (1) by direct contact with the infective person; (2) by contact with anything which has been in contact with an infective person; (3) by intercommunication between animals and man; (4) transportation by insects, as the common house-fly, mosquitos, gnats, ants, fleas, etc.; (5) by water or food; and (6) by the air. The Public Health Acts make it penal for an infective person to expose himself or herself in a public place or vehicle, and for articles of infective clothing to be pawned or sold. It is likewise penal to let rooms which have been occupied by a person suffering from infective disease unless and until the rooms have been disinfected. The room occupied by the infective sick is deemed infective until it has been disinfected, and the same is true of a vehicle which has been hired for the conveyance of the infective sick and of the contents of the room or vehicle.

The agency of insects in the transmission of certain diseases of this class is now well established, particularly of insects which seek their food in excrementitious matter and those which sting and suck the blood of the person. To the agency of the common fly must be largely attributed the widespread epidemic of enteric fever in South Africa during the currency of the war in 1900–1902, and to a more limited extent perhaps, the greater prevalence of that disease in privy-midden towns; indeed, flies fed on food containing cholera bacilli pass these uninjured in their excreta. The common flea is deemed by many to be a factor in the spread of plague, and *B. pestis* has been found in their bodies; and mosquitos—the *Anopheles maculipennis*, *Culex pipens*, and one or two others—have been proved to be important hosts of one form or another of the malarial parasite. Many other disease-bearing insects might be mentioned, as the tsetse fly in the production of the disease of that name among cattle, and the *Boöphilus bovis* in Texas fever of cattle. Of the water-borne zymotic diseases, cholera, dysentery, and enteric fever are probably the chief. These have been already discussed. Milk among foods is probably the most liable to convey infective matter, as it is one of the best natural absorbents of infective or septic matter, and moreover offers an excellent nutrient medium for the growth of organisms. Milk-borne epidemics of enteric fever, diphtheria, and scarlet fever are far from uncommon. Unused milk which has been exposed in a sick-room ought to be treated as slops, and should not be partaken of by healthy persons. In prevailing epidemics of these diseases the safest plan is to boil the milk for some minutes, in order to destroy all contained microbes and spores. Air-borne infection is probably the chief source of most of the zymotic diseases. Bacteriological examination of the air, street dust, and soil of populous places

indicates the enormous number of organisms contained therein, and, further, that the air is richer in organisms the drier the weather.

The proximate modes by which infective material enters the body are these: (1) *inhalation*; (2) *ingestion*; (3) *inoculation*; (4) *absorption*. In certain zymotic diseases the type of attack differs as is the chief organ attacked; for example in plague, in certain cases the type is pneumonic, in others bubonic, and in others septicæmic. So that while infective diseases have elective seats of action, in certain of them there may be more than one elect seat.

The means by which the spread of infective diseases is prevented or minimised, are the following, viz.: (1) *Prophylaxis*; (2) *Notification*; (3) *Isolation and Quarantine*; (4) *Disinfection*.

Prophylaxis is operative especially during the interval of an impending outbreak of zymotic disease and its actual appearance in a population. Prophylactic measures include: (1) general instructions to the people as to means, personal and domestic, best calculated to ward off the disease; (2) special attention to the working efficiency of sanitary measures, and the institution of protective measures, as for example, vaccination in small-pox; and (3) the establishment of a cordon between non-infected and infected inland countries or districts, or non-infected and infected ports in seaboard countries.

The other modes come into effective operation immediately the first case of the disease appears, and they aid in checking or limiting the further extension of the outbreak.

Notification of infectious diseases supplies a powerful instrument to sanitary authorities, first in enabling them to locate the area of the disease, to track its origin, to watch the lines of its extension, and to gauge its progress by the knowledge which is obtained of the number of persons attacked; and second, to concert suitable measures of isolation and disinfection to prevent its extension. The Public Health (Scotland) Act, 1897, section 47 (4), gives power to the sanitary authorities, to remove if necessary all the inhabitants of houses within an infected area to places provided by the authority, so that thorough measures of disinfection may be overtaken. The Infectious Diseases (Notification) Act of 1889, although at first a permissive or adoptive Act, was largely adopted by sanitary authorities throughout the country. It is still a permissive Act for England, but has been made compulsory for Scotland by virtue of the Public Health (Scotland) Act, 1897. When the Act is adopted in any urban or rural district, the duty of notifying the existence of any one of the diseases named in the schedule of the Act falls upon: (1) The parent or guardian of the sick person, and (2) upon the medical attendant. The scheduled diseases are: Small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus fever, enteric fever, relapsing fever, continued fever, and puerperal fever. It is competent for any Local Authority to add to the list of diseases above named, after due notice, conform to the terms of the Act, has been publicly given. Forms of certificate are supplied by the authority to each medical practitioner, for each of which, duly filled, a fee of 2s. 6d. is payable for a private patient, and of 1s. for patients in public institutions or in public practice. Failure to notify is attended by a fine not exceeding

40s. It ought to be observed that the Act does not confer powers upon Local Authorities to remove patients compulsorily, or to enter the houses of the sick. Such powers may, however, be obtained in a warrant from a magistrate, by virtue of the Public Health Acts. In order to derive the highest measure of benefit from this Act, it is necessary for local authorities to institute sufficient hospital accommodation for those who cannot efficiently be isolated at home, and in addition, reception-houses or houses for "contacts," *i.e.* those who have been in contact with the sick, for the lodgment of such persons during the incubation period of the disease and while their homes are undergoing cleansing and disinfection.

Isolation and quarantine are valuable means of checking the spread of disease, and although they do not mean the same thing subserve the same purpose. The former in practice means the separation of the infective sick from the healthy in such circumstances as will prevent, as far as can be, the spread of the disease. and for such periods of time as infectivity prevails. Quarantine means the separation from the healthy of persons, who although themselves not yet actively infected may become infective, and of things which may be the passive carriers of infection, from an infected area for such space of time as will demonstrate whether or not the former will become actively infected, and as will enable disinfection to be employed in respect of the latter. The practice of quarantine, however, does not cover the period of time (forty days) involved in the literal meaning of the word. It is usually confined to sea-going traffic in seaboard countries, and to passengers and luggage at frontier towns in inland countries. By the Convention of Venice of 1898, which was intended to prevent the spread of plague, it is incumbent upon the government of an infected country to institute measures to prevent the exportation from its infected area of merchandise capable of carrying the infection; non-compliance with this agreement enables the other countries to impose restrictions on persons or merchandise coming from any port of the infected country, notwithstanding the absence of plague from the port in question. The Quarantine Law of 1893 of the United States makes it unlawful for any vessel from a foreign port to enter any port in the United States unless and until a certificate of a clean bill of health has been obtained from the consular or medical officer of the United States at that foreign port; no vessel shall enter a port, or discharge its cargo, or land its passengers, except upon a certificate of the officer of health at the quarantine station; where an infected vessel arrives, it is remanded to the quarantine station for the necessary disinfection and treatment of vessel, passengers, and cargo, and, thereafter, on a certificate from the health officer that the vessel is free from infectious disease, or danger of carrying the same, it shall be admitted into port; when cholera or other infectious diseases in a foreign country may cause serious danger to the United States by its or their introduction, power is given to the President to prohibit, in whole or in part, the introduction of persons and property from such countries or places, and for such period of time, as he may deem necessary.

Ships which come from an infected port are required to lie out

CHAPTER XI.

DISINFECTION.

Disinfection includes all those processes the effect and object of which are the destruction of infective matter, the nature of the process being regulated by the character of the material which encloses or carries the *materies morbi*. A disinfectant may be defined as an agent which destroys the power of infective matter to further produce disease. Unfortunately the term is used indiscriminately to cover a number of the most valuable as well as the most inept substances. This has doubtless arisen from the nebulous conceptions which formerly existed regarding the entity of infective matter. Often associated with disagreeable odours, infective matter was supposed to be rendered inert by the use of deodorants. Since the microbic constitution of infective matter became established, however, such views have had to be revised, and the disinfecting power of any substance or agent must now be gauged by the measure of its capability to destroy micro-organisms and their spores.

Disinfectants may be divided into: (1) *Physical Agents;* and (2) *Chemical Substances.*

The principal physical agents which are inimical to microbic life are: (*a*) *Light;* (*b*) *Heat;* (*c*) *Cold.* Light, especially direct sunlight, is very destructive of micro-organisms after variable periods of exposure. Experiments have abundantly proved that such exposure is rapidly lethal to the organisms of erysipelas, enteric fever, tubercle, and anthrax, and in the case of others, if they are not actually killed, that their vitality and virulency are at least minimised. Such facts as these indicate the need for good lighting of houses, the value of open spaces and of good building regulations, and the prevention of smoke-production. As an adjuvant to good light is abundance of air. Of air as a germicide it may be said, that when it is fresh and abundant, it so dilutes infective matter as to reduce the virulency of organisms, if not indeed, to destroy the organisms. As has already been said, the area of infectivity of typhus and other diseases is limited by the free diffusion of air, and in the case of anærobic organisms which are not facultative aërobes, it arrests their operation entirely. The combination of air and sunlight has an important effect in the destruction of micro-organisms in water and sewage. The effect of such combination is included in the purifying effects of sedimentation in water-supplies.

Heat is a valuable bactericide when applied either as dry air, moist air, water, or steam. It is best adapted for the disinfection of body-clothing, bed-clothing, and room furnishings, as carpets, rugs, cushions, etc., which have been exposed in an infected room. For

clothing which will not be injuriously affected, boiling in water for twenty minutes to half-an-hour will completely disinfect. Such treatment is suitable for cotton and linen fabrics. For woollen fabrics, feathers, hair mattresses, etc., however, the most suitable treatment is by heated moist air, or by steam. Dry heated air, even under pressure, has been found by different experimenters to be inefficient, unless at such temperatures as are bound to scorch certain of the materials subjected to it. In order to destroy organisms and spores a temperature between 212° and 220° F., is necessary, and it has been found impossible by dry heated air to obtain this temperature in the interior of a mattress even after long periods of exposure. Moreover, according to the experiments of Koch and others with dry heated air, an exposure of four hours to a temperature of 220° F., is necessary to destroy spores, whereas with steam at 212° F., exposure for five minutes will effect the purpose. Consensus of opinion, arrived at by direct experimentation, is now solely in favour of moist heat. In an efficient disinfector where moist steam is used, the following are essential points: (1) that the steam under pressure should permeate thoroughly the articles to be disinfected; (2) that the temperature of the steam should be between 221° and 270° F.; and (3) that the apparatus is so constructed that, alternately, hot dry air and moist steam within the foregoing range of temperature should be passed into the chamber containing the articles to be disinfected. The disinfector constructed on the Washington-Lyon principle by Messrs. Manlove, Alliott & Co. is one of the best, and a description of the mode of using it will suffice for this type of disinfector of which there are several kinds with insignificant differences, and many makers.

This disinfector, which is oval in shape and constructed of steel, consists of an outer and inner chamber, the former being called the "jacket," in respect that it envelops the latter. When the apparatus is working, it is filled with steam at a pressure of 20 lbs. per square inch and of a temperature of 267° F. In the inner chamber is a movable cradle or basket, made of galvanised iron wire, in which the articles to be disinfected are placed. By means of valves, communication may be established between the outer and inner chamber, both for filling the latter with steam and for emptying it partially of air. The disinfector, then, being in working order, the following is a description of the process of disinfection from beginning to end: The inner chamber door is opened, the cradle is pulled out, and the articles are placed in it. The cradle is then pushed back into the chamber, and the steam-tight doors are shut. Steam under the conditions above mentioned having been meanwhile filling the outer chamber, the air of the inner chamber is partially exhausted by the action of a steam nozzle, the effect being to produce a partial vacuum within the chamber. At this stage the communication between the two chambers is opened, steam rushes into the inner chamber under considerable pressure, and forces itself into the pores of the articles. This part of the process lasts for not less than twenty minutes, but the time may be extended if the nature of the articles deem it necessary. The communication between the chambers is now closed, the steam of the inner chamber is now blown out, a partial vacuum is once more established, and hot air

takes the place of the steam. The hot air takes up any moisture which may have become condensed upon the articles, which are now taken out of the cradle, the process of disinfection being completed. In municipal disinfecting establishments where large quantities of materials must be handled daily, it is essential that disinfected goods should not be mixed with the infective. This is overcome by dividing the inlet side from the outlet side of the disinfector by a partition wall which extends the whole length of the apartment; thus the infective articles put into the apparatus on the inlet side, after disinfection are taken out on the outlet side, and commingling is thus prevented. To the same type of apparatus belongs the disinfector of Messrs. Goddard, Massey and Warner, with this essential difference that the pressure—20 lbs. per square inch—in inner and outer chamber is identical, and the steam is not *superheated*. In the Continental disinfectors, built on the Geneste and Herscher lines, there is no outer chamber or jacket, the steam pressure in the disinfecting chamber is about 10 lbs., and the steam is not superheated. The term *superheated* demands a word of explanation. The temperature at which steam is generated depends upon the pressure to which the heated fluid is subjected. At ordinary atmospheric pressure steam is generated from water at 100° C., or 212° F. If the pressure is increased, the temperature of boiling-point, and, consequently, of steam formation, is raised as is the degree of pressure; thus, if the pressure be two atmospheres, the temperature of steam-formation is 249° F., if three atmospheres, 273° F. Steam generated at these temperatures is said to be saturated, that is, it cannot do work by expansion, and it undergoes condensation on cooling. When, however, this saturated steam is further heated, it is said to be superheated; that is, its temperature being higher than the condensing point relative to its actual density and volume, it can do work on expansion and can be cooled to some extent without undergoing partial condensation; in other words, superheated steam comports itself like a perfect gas.

But other disinfectors have been constructed on different principles. In that of Van Overbeck de Meyer, the steam is generated in the outer chamber at ordinary pressure, and is passed into the inner chamber by an opening in the top. In this machine the temperature is 212° F. In the machine invented by Dr. Thresh, Medical Officer of Health for Essex, the temperature of the steam is 225° F. The principle upon which it is constructed is that water containing a saline substance in solution boils at usual atmospheric pressure at a higher temperature than ordinary water. The water in this apparatus is charged with calcium chloride, and the machine is so arranged that the calcium salt once added may do work for a considerable time by water being added to it as required from an automatic feed cistern. The generated steam having a temperature of 225° F., is made to circulate in a pipe which passes through this boiling solution. The machine possesses an inner and an outer chamber, the latter containing the saline solution, and into the former are placed the articles to be disinfected. When the temperature of the inner chamber reaches the above temperature, the steam at the like temperature is made to enter, and thus acts upon the articles. The time allowed for

disinfection is the same as in other machines. When the disinfecting process is complete, the course of the current of steam is turned by means of a lever from the inner chamber into the flue of the machine, and thus the inner chamber is converted into a dry air chamber, any moisture which condenses upon the articles is vaporised, and they come from the machine dried. It is claimed for this apparatus that it attains (1) uniformity of temperature; (2) rapidity and efficiency of penetration; (3) maximum temperature in the interior of the articles being disinfected; (4) dryness of articles on removal. Further, it has the merits of simplicity, non-requirement of skilled labour, and of safety.

Cold.—The agency of cold cannot be looked upon as a germicide. It may inhibit for the time being the growth of organisms, but that is all that can be said of it. Organisms can withstand exposure to very low temperatures without apparent prejudice. The experiments of M'Fadyen[1] and Rowland[2] absolutely prove this. They exposed a variety of organisms, pathogenic and non-pathogenic, sealed in fine quills, to the action of liquid air—temperature, $-312°$ F.—for seven days, and at the end of that time they proved by culture experiments that the vitality and cultural characteristics of the organisms were in no way impaired.

Chemical Disinfectants.—A large number of substances popularly called disinfectants are merely deodorants or antiseptics, and have no virtue as germicides; and since in practical disinfection destruction of organisms and spores is the objective point to be aimed at, they are worse than useless. The potency of any germicidal agent used depends entirely upon its strength, and upon its applicability for this purpose to the medium in which the organisms are located. When the germicidal value of any substance is spoken of, it ought to be with reference to its strength in the fluid in which it is being used, and not to its strength in the solution which is added; thus if it be said that a certain disinfectant is destructive of organisms in a 2 or 5 per cent. solution, it is meant that the fluid containing the infected substance must contain 2 or 5 per cent. in its whole bulk, and not merely that a solution of that strength is to be added. To the class of germicides belong: (*a*) mercuric chloride; (*b*) biniodide of mercury; (*c*) chlorine in gaseous form, or as chlorinated lime; (*d*) formaldehyde; (*e*) chloride of zinc; and in addition, when used in sufficient volume for aerial disinfection; (*f*) sulphurous acid gas; (*g*) iodine vapour; and in the disinfection of liquid or pultaceous substances; (*h*) the sulphates of iron, copper, and zinc; (*i*) cupralum; (*j*) carbolic acid; (*k*) preparations of cresol; and (*l*) the mineral acids.

The following Table indicates the substances which act efficiently as germicides when used of the named strengths.

[1] *Proc. Roy. Soc.*, vol. 56.
[2] *The Lancet,* April 21, 1900.

TABLE XXIA.

Table of Efficient Strengths of Disinfectants as Germicides.

Disinfecting Agent.	Strength and Medium in which to be Used.
Mercuric Chloride	1 in 1000 of water (70 grains per gallon). Solution to be aided by addition of common salt, and coloured with laundry blue. This may be used for disinfection of body- and bed-linen, and liquid excreta. The proportions proposed by the English Local Government Board are: ½ oz. mercuric chloride, 1 oz. hydrochloric acid, 5 grains commercial aniline blue—in 3 gallons of water. A solution of 1 in 4000 is excellent for washing woodwork and floors.
Mercuric Iodide	1 in 1000 of water for infected linen and stools; 1 in 2000 for hands and liquid stools; 1 in 4000 for woodwork and floors. Solutions ought to be rendered odorous by thymol, eucalyptol, or wood-naphtha.
Chlorinated Lime, or Bleaching Powder	4 parts per 100 of water (6 oz. to 1 gallon of water) for solid and liquid excreta. When used for the former, to be permitted to soak for about one hour before vessel is emptied. One part per 100 is excellent for hand-washing after visitation to sick-room and handling of patient.
Carbolic Acid	5 per cent. solution in water (1 in 20). Official strength used in Berlin, 1 in 18. To destroy bacteria a 10 per cent. solution is needed; water, however, will not dissolve so much.
Copper Sulphate	5 per cent. solution in water. To be used for disinfecting stools. Contact not less than one hour.
Zinc Chloride (Burnett's Fluid)	1 in 10 of water; for stools, as above.
Sulphurous Acid Gas (compressed in cylinders at three atmospheres' pressure)	Exposure for twelve hours to 4 vols. per cent. in a moist medium. 1½ lbs. of sulphur per 1000 cubic feet of air-space only gives 1·75 per cent.
Chlorine Gas	·5 to 1 vol. per 100 vols. of air.
Hydrochloric Acid Vapour	·05 to ·1 vol. per 100 vols. of air.
Bromine	1 in 2000 of water for solid excreta. Objectionable to user by reason of irritancy of vapour given off.
Formaldehyde	Used as a spray with steam, half a pint of formalin per 1000 cubic feet. Used as a gas or vapour, one pint per 1000 cubic feet. The formalin of commerce is a 40 per cent. solution of formaldehyde in water. If stools are mixed with an equal volume of a 10 per cent. solution, disinfection is rapidly produced.

It is important that disinfection should be carried out as efficiently as possible in practice. When a patient is confined to a sick-room, disinfection must not only follow the vacation of the room, but it must be concurrent with the illness, since the discharges and fouled clothing must be disinfected. As a safe, working principle it should be held that everything which comes from the body of the patient, which has

warmed blanket which has been handed in for the purpose, and then re-clothed on arrival in the new room. In scarlet fever and in diphtheria especially, the patient should use for some time after apparent recovery, some form of antiseptic gargle to destroy lingering organisms. The vacated room and its contents now require to be disinfected. The clothing which the patient has left behind, that of the nurse, the bed-clothing, and the room furnishings must be disinfected either by the householder, or by the sanitary authority. In rural districts and villages it usually falls to be done by the householder; in populous districts it is commonly done by the sanitary authority. The householder should be instructed how to carry out the process. All articles of clothing, bed-clothing, etc., should be steeped in the room for a couple of hours in a solution of 1 to 2000 corrosive sublimate, should then be roughly wrung, and in a covered vessel be removed to the wash-house, there to be submitted to boiling and the usual cleansing process, after which they should be exposed in the open air for twenty-four hours. Mattresses, pillows, cushions, etc., should be left in the room to be disinfected by a gaseous disinfectant, and, after being sponged over with 1 to 40 carbolic acid solution, should thereafter be removed into the open to a place a little distance from the house, and be left exposed to the air under cover if need be for several days. Mattresses soaked with discharges cannot be disinfected in this way, and therefore ought to be burned, as should also any worn-out clothing. In small-pox, especially in confluent and fatal cases, mattresses ought to be burned whether old or new. The woodwork, floor, and furniture of the room, the walls and ceiling fall next to be dealt with. These are usually exposed to the action of a gaseous disinfectant, of which sulphurous acid and formaldehyde are perhaps the most practicable. Gaseous disinfectants have been hitherto used for disinfection of the air of the room, but this so-called aerial disinfection is at best but a delusion, for if ventilation of the room has been attended to, little fear need be entertained of its infectivity. What do demand attention, however, are the microbes and spores which have become constituent parts of the dust which has settled in the crevices, corners, and other points of lodgment in the room. In Continental countries little or no attention is paid to aerial disinfection, while much is paid to the deposited dust. Hence two methods of room disinfection prevail; one devoted mainly to aerial disinfection, as in Great Britain, the other to disinfection of room dust, as in France and Germany. Each method requires further description.

The English Local Government Board recommends that 1½ lbs. of sulphur, mixed with a liquid combustible as alcohol, or a solid, as nitre, should be burned for each 1000 cubic feet of air space in the room which has been made as air-tight as possible, and the sulphurous acid gas which is produced allowed to act for 24 hours. But this only produces in the space named 1·75 per cent. of gas, whereas direct experiment shows that 4 per cent. are necessary. Apart from this, however, to burn solid or powdered sulphur is not an easy matter. This uncertainty of action, however, is overcome by the use of cylinders or siphons of compressed liquid sulphurous acid gas. The gas is compressed at a pressure of about 45 lbs. per square inch, and it is liberated by cutting the projecting soft lead pipe. Before using sulphurous acid, and in order to make its action efficient, the apartment and the contained articles ought to be moistened with water, otherwise much of its potency is lost. Instead of this gas, chlorine is sometimes substituted. But in order to generate the necessary lethal amount from chlorinated lime, it is necessary to use 15 lbs. of that substance and 22 lbs. of hydrochloric acid per 1000 cubic feet of space, which is impracticable. Doubtless when it is manufactured in the compressed liquid form it will be more serviceable, although it corrodes metallic objects and its fumes are exceedingly pungent and irritating. A very potent gaseous germicide, however, has been discovered in methylaldehyde or formaldehyde (CH_2O), commonly met with as formalin—a 40 per cent. solution of the former in water—which is the highest percentage capable of being dissolved in that medium. As sold commercially, it may be slightly acid in reaction due to traces of formic acid. Discovered by A. W. Hoffmann in 1867, it was not till 1886, however, that its germicidal properties were revealed by Loew and Fischer, and not till 1892 that attention to its practical use as a disinfectant was attracted by a communication to the French Academy of Sciences by Trillat. Since that time it has been largely used as a preservative of milk and other foods. If

attempts are made to concentrate the watery solution or to condense the vapour, a solid substance is formed, crystalline in character, called *paraformaldehyde* ($C_3H_6O_3$), which when heated melts at 171° C., but on heating it gently it vaporises into gaseous formaldehyde. When borax or chloride of calcium, however, is added to formalin, and the mixture is heated under pressure in a closed vessel, the above change does not ensue. Formalin does not possess an offensive odour, but formaldehyde vapour is very pungent and irritating, and its odour is apt to be lasting. It acts upon albuminous substances and forms compounds with them; for example, it changes egg-albumen into a substance insoluble in water. The vapour or liquid does not attack metals, does not act prejudicially upon delicate articles of attire or furniture, and does not bleach colours. Its action is very lethal upon micro-organisms when used either as a vapour or as a liquid. The vapour is generated by means of autoclaves, lamps, or generators, and is dissipated either in the form of pure vapour or of vapour mixed with steam, and the substances used are either liquid formalin, or the solid substance paraformaldehyde or *paraform* as it is called commercially. Of the many forms of apparatus which have been devised, the principles of their action may be used to divide them into three classes, viz., (*a*) those in which the pure vapour is driven off from liquid formalin under pressure or without pressure; (*b*) those in which combined vapour and steam are disengaged; (*c*) those in which the vapour is liberated from solid tablets of paraformaldehyde. Trillat's autoclave may be taken as a type of the first. It consists of a reservoir to hold the formalin, to which chloride of calcium is added to prevent polymerisation, the mixture being called formo-chloral; a pressure gauge; thermometer; an outlet whereby the gas escapes which is regulated by a valve; and a lamp. When the apparatus is to be used the cover of the reservoir is bound down, the lamp is lit, and the formaldehyde vapour passed by means of the keyhole into the room to be disinfected. The instrument of the Sanitary Construction Company acts without pressure, since the formaldehyde is passed in regulated supply into a heated coil and is thus rapidly vaporised. The Breslau generator may be taken as a type of the second class. From it is generated a mixture of the vapour and steam, the boiling solution used being a mixture of one part of formalin and four of water. The solution is heated by a spirit lamp, and the amount of spirit to be used should be in proportion of one-fourth of the volume of the disinfecting solution, so that the heating should be exhausted before the complete vaporisation of the solution. The Schering generator is a type of the third class. In it the solid paraformaldehyde is used in the form of tablets, each of the weight of one gramme. The requisite number of tablets is placed in a basket made of iron and wire gauze over a spirit lamp of several wicks, both being surrounded by an open-mouthed iron casing. Into the lamp are put 2 c.c. of spirit for each tablet used, and the wicks only project $\frac{1}{12}$th of an inch, so as to give just the amount of heat necessary to volatilise the tablets, and to prevent the possibility of burning them. In addition to these forms of apparatus may be added another which was advocated by Schlossman[1] and Walther. Schlossman is of opinion that in the methods already described the bulk of the formaldehyde does not escape as such, but is converted into polymers. This polymerisation, he affirms, is prevented in his method by the use of glycerine. Lingner's apparatus to carry out this method consists of a vessel in which water is boiled, from which the steam passes into a reservoir which contains formalin and 10 per cent. glycerine, which mixture is called by them *glycoformal*. From this reservoir four pipes emerge, by which the mixture of steam and glycoformal is made to rapidly fill the room to be disinfected. Schlossman states that a room of 60 cubic metres can be so filled with vapour in 10 minutes that an electric lamp, placed in the centre, can no longer be seen, and that all organisms are killed in about three hours at the outside. The advantages which he claims for his method are: (1) absolute sterilisation; (2) no danger of explosions; (3) cheapness; (4) the total disinfectant powers of the gas are obtained; (5) and that the operation is complete in three hours. At the end of the time the windows of the room are thrown open for half-an-hour, after which they are again closed, and liquid ammonia is placed in the room to get rid of the odours, then after a short time the room is again thrown open, and the odour of the disinfectant has disappeared. The effect of ammonia upon formalin is to form an inodorous compound, *hexamethylentetramin*

[1] *Berl. klin. Woch.*, June 20, 1898.

($NH_4 + 6CH_2O = (CH_2)_6N_4 + 6H_2O$). In addition to these methods of disinfection formalin may be sprayed upon the walls, furniture, etc., of the apartment by different forms of atomisers or pulverisateurs.

Amount Required for Room Disinfection.—The general rule, when formalin is vaporised, is to employ a pint (20 ozs.) of the fluid for every 1000 cubic feet of space, and of solid paraformaldehyde, 60 tablets or 60 grammes, with a minimum of exposure of four to ten hours. When used in the form of spray the strength of solution ought to be 1 part of formalin to 50 of water, and the total quantity used to be regulated by the size of the apartment.

Efficiency.—Diverse opinions have been entertained as to the efficiency of this gaseous disinfectant in respect of its power of penetration, but direct experimentation has proved that it disinfects only surfaces which are smooth or polished, that it is not reliable in its action upon dust, that it does not penetrate the interior of bulky objects as bedding or upholstered furniture, that it requires not less than ten hours to attain its maximum efficiency, and that it is not cheaper than, if indeed as cheap as, other methods. Some experimenters as Abba go the length of saying that it cannot be deemed of practical utility as a disinfectant for room disinfection generally.[1]

Whatever form of gaseous disinfection is employed, the room must be thrown freely open for some time thereafter to permit the odours to be dispelled before further cleansing operations are proceeded with. Thereafter the floor, woodwork, and furniture must be washed with 1 in 1000 corrosive sublimate solution, the wall-paper if present stripped, and if not, the walls and ceiling should be lime-washed, the windows remaining open night and day all the while.

In view of the inefficiency of gaseous disinfectants to sterilise the dust deposited in a room, we come back after all to the conclusion that the prime object to be attacked is the dust, since in it will be located live micro-organisms and spores. There is therefore much to be said in favour of any procedure which initially deals with this dust. The methods adopted in France and Germany are calculated to do this. In Paris infected rooms are disinfected by a 1 in 1000 corrosive sublimate solution which is distributed all over the apartment and its contained furniture, in the form of a fine spray by means of a *pulverisateur*. This machine, which is of different sizes and which may either be carried on the back of the operator or moved about on wheels, depending on the amount of work to be done, is operated by the workman, who while he is engaged in the work is clad in an overall uniform, which when the work is done is taken off, is packed in a small tin case, and then returned to the disinfecting station. The charwoman does the rest. It may be objected to this method that the workmen are exposed to the poisonous effects of the disinfectant; but notwithstanding the many thousands of operations which are performed annually little evidence of toxic effects has been seen. This is a risk, however, demanding attention. But if, as in Paris, the workmen are instructed as to the poisonous nature of the solution, such risks are reduced to a minimum. No harmful effects on the inmates have been recorded after re-occupation of rooms so treated.

Esmarch's method, which is carried out in Berlin, is also a method for dealing with the dust. The material used consists of chunks of ordinary German bread forty-eight hours old. These are used by workmen for rubbing down the walls and ceiling of the room, by which the dust adheres to the bread, which is then burned. The walls are then sprayed with a 2½–5 per cent. solution of carbolic acid, the floor, woodwork, and furniture treated with the like solution, in this way accomplishing the disinfection of the room. If the various methods of disinfection are reviewed, it will be apparent that they all involve expenditure of time and money, and that none of them can be done cheaply. Objections may easily be offered to any one plan as compared with another, but if disinfection is not to be merely a name, then both labour and money must be expended. We are of opinion that spraying operations are by far the most likely to be effective as they are certainly the most rational, since the dust is attacked and prevented from becoming air-borne, and that gaseous disinfection should be abandoned. Such methods of disinfection have also the merit that they compel the cleansing of the whole room, and there can be little doubt that much disinfection is achieved by the liberal use of soap and water and the freedom with which air is allowed to circulate in the apartment while cleaning operations are being carried on.

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[1] *Centralbl. f. Bakt.*, Band xxviii. Nos. 12, 13, 1900.

In cerebro-spinal meningitis.

In Section 11 enacts that any payment made to a medical practitioner in
pursuance of this Act shall not disqualify the practitioner for serving
as a member of council a county or burgh council, of a sanitary authority,
guardian of the poor, or in any municipal or parochial office: and
a medical practitioner, who is the M.O.H. from receiving the fee for
notification which he may have made as practitioner

CHAPTER XII.

SANITARY LAW RELATING TO INFECTIVE DISEASES.

It is essential that medical practitioners should have some knowledge of the laws relating to infective diseases, not only for their own guidance, but also to enable them to advise their clients when such advice is asked. The main provisions of all Acts of Parliament dealing with sanitary matters are intended to conserve the public health by the removal of all causes which may imperil it, and to prevent the origin and spread of infective diseases.

In none of the Public Health Acts is there any definition of what constitutes an infectious disease, notwithstanding that such diseases are mentioned in various Acts.

In 1889, the Infectious Disease (Notification) Act, 1889,—52 & 53 Vict. cap. 72—became law, and for the purposes of the Act in section 6 a ~~scheduled~~ list of infective diseases was given. The diseases embraced in the schedule are the following, viz.: small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlatina or scarlet fever, and typhus, typhoid, enteric, relapsing, continued, and puerperal fevers. It will be observed that some of the other infective diseases as measles, whooping-cough, chicken-pox, influenza, plague, and others, are not included; but a Local Authority may, by provision of section 7 of the Act, after due resolution and publication of its intention, add one or more of the above to the list; indeed, this has been done by various local authorities in respect of measles, choleraic diarrhœa, plague, and others. The burden of notifying the existence in a house of one or other of the infective diseases above named falls upon (1) the head of the family or other responsible person, and (2) upon the medical practitioner in attendance. Failure to perform this duty is penalised after conviction by a fine not exceeding forty shillings. Section 4 provides that duly printed forms for notification purposes shall be sent to each medical practitioner, who shall, for the notification of disease in respect of each case in private practice, and for each case in his practice as medical officer of any public body or institution, receive a fee of two shillings and sixpence and one shilling respectively.

accepted by every Local [illegible] district, in which it was made compulsory by section 2,

The Act being a permissive or adoptive Act, ~~section 5 records the procedure for its adoption by an urban or rural district; and section 7, the procedure by which an addition to the scheduled list of diseases may be made.~~ In Scotland, however, by section 44 of The Public Health (Scotland) Act, 1897, the adoption of the Notification Act is compulsory upon all local authorities. The payment of fees under this Act to a medical practitioner does not, in terms of section 11, disqualify him for serving as member of the council of a county or borough, or in other like capacity, nor, although he himself is the

and in England and Wales by the Infectious Disease Notification Extension Act, 1899. In Ireland, therefore, the Notification Act is now in operation

medical officer of health, is he debarred from receiving fees. The Notification Act applies to the United Kingdom.

The provisions of Public Health Acts in which the medical practitioner has especial interest are those which deal (1) with the infective person; (2) with the infective place; (3) with infective things. The subjects may, therefore, be dealt with in that order.

I. In Respect of the Infective Person.—It is forbidden, under a penalty, for any person suffering from an infectious disease (1) to wilfully expose himself or for any person to expose any one suffering, in any public place or conveyance, without taking proper precautions against spreading the disease; (2) to enter a public conveyance or ship, or to cause an infected person to be conveyed in such way; (3) to be conveyed knowingly by the owner or person in charge of such conveyance or ship, in which circumstances the conveyance must be disinfected by the local authority. (It is not forbidden, however, for infective persons to travel by railway train or by ship, if they are conveyed within an ambulance waggon or other vehicle provided or approved by the local authority;) (4) to engage, knowing that he is suffering from such disease or is living in an infected house, in the operation of milking any animal, of picking fruit, or in connection with any trade or business calculated to spread disease; (5) a parent or other person in care or charge of a child who is or has been suffering from such disease or who resides in a house where such disease is or has been existent within a period of three months, who knowingly or negligently permits such child to attend school without a certificate from a qualified medical practitioner that such child is free from disease and infection, and that the house and contents exposed to infection have been duly disinfected, shall be liable to a penalty not exceeding forty shillings. The teacher or person in charge of the school is culpable in the same case, the penalty being the same.

Removal of Infective Persons.—Where an isolation hospital has been provided in any urban or rural district, any person suffering from such disease who is without proper lodging or accommodation, or who is lodged in a room occupied by others than those in attendance, or who is on board any ship or vessel within three miles of the coast, may, on a warrant by a magistrate, be removed from thence to a hospital, or alternatively, the persons not in attendance upon the patient may be removed from the house by order of the magistrate, in which case the local authority must provide suitable accommodation for them. In like manner an infective person in a common lodging-house may be removed to hospital. Such provisions are to be interpreted by the existence or non-existence of means of efficient isolation and facilities for disinfection. All of the foregoing provisions only apply to the living infective person. What of the dead? No precautionary or prohibitory provisions exist in any of the Public Health Acts regarding the removal in a public conveyance from a house to a place of sepulture, of the body of a person who has died of infective disease, provided that the conveyance is one reserved for the purpose. But it is unlawful to transport for burial, or for other recognised means of disposal, the body of a person who has died of infective disease, unless and until it has been certified by a legally qualified prac-

titioner that precautions requisite for the public safety have been adopted. Moreover, it is penal for an undertaker or any other person to remove in the above way such a body without having obtained the above necessary certificate. While the foregoing is now the law of Scotland (P. H. (Scot.) Act, 1897, section 69, sub-section 3), the law of England and Ireland—Infectious Disease (Prevention) Act, 1890—is exactly the same. Should in any section of the kingdom the vehicle employed for this purpose not be reserved for the carriage of dead bodies, notification that the dead body is infective must be made to the owner or driver thereof, and the vehicle thereafter be disinfected, otherwise it shall be an offence. Where a public mortuary has been provided, and where the body of a person who has died of infectious disease is retained in a room in which persons live or sleep, or is retained longer than 48 hours in a room used as a dwelling-place, sleeping-place, or work-room, or where any dead body is retained in a house, room, or ship under circumstances which might endanger the health of the inmates or of neighbours, such may be removed on warrant to the public mortuary. The duty of interment of such bodies falls upon the Local Authority when the friends or relations of the deceased are unable to do so, or do not inter within the time above specified, in which latter case the Local Authority may recover the expenses from the friends or relations (section 69, sub-sections 1 and 2, P. H. (Scot.) Act, 1897).

Again, in view of the practice of certain persons of "waking" the dead, it has been made penal in the Scots Act (section 56, clause *d*), if any one wakes or permits to be waked in any place over which he has control the body of an infective person.

If a person dies in any hospital from any infectious disease, and if it be certified by a legally qualified practitioner that in order to prevent the spread of the disease the body should not be removed except for burial, it shall not be removed except to be taken direct to the place of burial. Wilful disobedience carries with it a penalty not exceeding £10 (P. H. (Scot.) Act, s. 63; P. H. (Lond.) Act, 1891, s. 73; and Infectious Disease (Prevention) Act, 1890, s. 9).

II. In Respect of the Infective Place.—From what has been said, it is incumbent upon the owner or driver of a public conveyance or master of a ship to disinfect the said conveyance or ship as soon as it comes to his knowledge that an infective person has been carried therein; the loss and expense incurred to be recoverable from the person or his friends. The same is true of a public conveyance other than one reserved for the purpose, which has been used for the carriage of a dead body. In like manner the room occupied during an infective illness must be disinfected at the termination thereof, either: (1) by the householder himself at his own expense, and to the satisfaction of a legally qualified medical officer; or (2) by the Local Authority.

Any person who lets for hire, or shows for the purpose of letting, any house or part thereof, and who on being questioned by the person negotiating for the hire as to whether within the previous six weeks infective disease existed therein, makes a false answer, shall be liable to a fine not exceeding £20, or imprisonment, with or without

hard labour, for a period not exceeding one month (P. H. (Scot.) Act, s. 52; P. H. (London) Act, 1891, s. 64); any person who, after occupying a house or part thereof in which infective disease has existed within six weeks previously, fails to have the house and its contents disinfected, or to give to the owner or occupier notice of the existence of said disease, or who makes a false answer on being questioned regarding said existence, shall be liable to a like monetary penalty; and any one who knowingly lets for hire any house or part thereof in which infectious disease has existed, without house and contents having been disinfected to the satisfaction and upon the certification of a legally qualified practitioner, is liable also to a like penalty. This section (51, sub-section 2) includes the keeper of an inn or hotel.

III. In Respect of Infective Things.—Any one who gives, lends, sells, pawns, transmits, removes, or exposes, or permits to be washed or exposed in any wash-house or washing green which is used in common by persons other than the family or household to which the infected person belongs, any bedding, clothing, or other articles which have been exposed to infection, without previous disinfection, shall be liable to a penalty not exceeding five pounds (P. H. (Scot.) Act, s. 56; P. H. (Lond.) Act, s. 68). This does not apply to articles transmitted under proper precautions for purposes of disinfection. Section 47 deals with the need of disinfecting all articles in a house which have been exposed to infection on notice being served upon the occupant or owner by the Local Authority, and sub-section 5 authorises said Local Authority to compensate said occupier or owner for any unnecessary damage caused to such articles on being disinfected by said Local Authority; section 48 deals with the disinfection or destruction of bedding, clothing, etc., on notice being served for the delivery thereof to an officer of the Local Authority, and sub-section 2 authorises compensation; section 49 compels, on proper cause shown, persons engaged in washing or mangling clothes to furnish a list of owners of clothes; and section 50 penalises any one who knowingly casts, or causes or permits to be cast, into any ash-pit, or otherwise exposes any matter or article infected by infectious disease, for each offence and continuance of the offence. The following may be taken as illustrative cases, viz: (1) trafficking in any article from any infected room; (2) carrying infected articles through the public streets, or sending the same in a public conveyance; (3) washing infected clothing in a wash-house which is common to other houses, or sending the same to a public laundry; (4) making fabrics for warehouses or for private persons in an infected house, and transmitting the same to the warehouse or private person when made; (5) pawning infective articles; (6) selling food of any kind in a shop attached to a dwelling-house in which infective disease exists; and (7) transmitting infected bedding or furniture to upholsterers or public cleaning establishments. The term "matter infected by infectious disease" would include such things as excreta, poultices, wall-paper, or vomited matters which are cast into a receptacle in a public place without previous disinfection. Where a medical officer of health has evidence that persons in his district are suffering from diseases that are attributable to the milk-

supply from any dairy, or that the milk from any such dairy is likely to cause or to have caused such disease, he shall visit the dairy and examine every person connected therewith, and a veterinary inspector shall examine the animals therein and report to the Committee of the Local Authority (P. H. (Scot.) Act, s. 58 ; P. H. (Lond.) Act, s. 71—Infectious Disease (Prevention) Act, s. 4). Sub-section 2 gives the medical officer of health power when required to communicate with the local authority of the district whence the milk has come to any dairy in question, and such local authority shall be bound forthwith, by its medical officer, to examine said dairy which is suspected and the persons connected therewith, and by a veterinary surgeon, to examine the animals therein, and the medical officer of health of the second-mentioned local authority shall forthwith report the results of said examination along with the report of the veterinary surgeon to the first-mentioned local authority; sub-section 3 gives a local authority power to order the dairyman to cease the supply of milk, where the facts warrant such a step, for such time as may be deemed necessary. Section 61 empowers the local authority, on the fact being certified that the outbreak or spread of infectious disease is attributable to milk supplied from a dairy or dairies, to demand from the dairyman whether within or without its district, a full and complete list of the names and addresses of all his customers within its district, so far as known to him, for which the dairyman shall be remunerated on a scale laid down in this section.

By the Regulations as to Cholera, Yellow Fever, and Plague, issued by the Local Government Boards, and which Regulations of the Scottish Board became law in Scotland in January 1898, certain important duties are placed upon Local Authorities having a seaboard, or having a part of their district abutting upon a port. These duties may be briefly summarised as follows: (1) The Regulations deal with ships' crews and passengers, and with ships coming from infected ports ; (2) with ships having on board passengers in a filthy or otherwise unwholesome condition ; (3) with the bilge-water, water-ballast, and water-supply of ships.

It is enacted that the master of every ship infected with Cholera, Plague, or Yellow Fever shall when within three miles of the coast cause a large flag of yellow and black, borne quarterly, to be hoisted at the mast-head, and shall keep it hoisted the whole time between sunrise and sunset, and that no person shall leave such ship until it shall have been visited by the Customs Officer and the Medical Officer of Health. Any ship is deemed infected in which, during the voyage or during its stay in the port of departure or in a port of call, there is or has been any case of the diseases named in the Regulations. During the currency of the Regulations, the following procedure shall be adopted in respect of any ship arriving from foreign parts, viz. : It shall be visited by the Officer of Customs who shall ascertain whether or not said ship is infected, and if he has reason to suspect that the ship is infected, shall require the master or surgeon of the ship, if there be one, to give in writing a true answer to the question, viz., whether any case of the diseases named in the Regulations has occurred in the ship at any point of its progress. If the ship is infected, or there is reason to

suspect this, the Customs Officer shall order the ship to be moored in such position as he shall direct, during which period of detention no one shall leave the ship. Thereupon the Customs Officer shall give notice to the Local Authority of these facts, and thereafter the ship shall be visited by the Medical Officer of Health, who shall at that visit examine every person on board, and in the event of finding any illness due to the above diseases, or likely to develop into such, shall certify in writing accordingly, a copy of which certificate shall be handed to the master of the ship, and he shall retain the original, or transmit it to the Local Authority, which is held bound to likewise inform the Local Government Board. Every person suffering from one or other of the diseases named shall, if his condition admit, be removed to a hospital or other suitable place set apart for the purpose by the Local Authority; if on the other hand the patient be too ill to be removed, the ship shall remain subject to the control of the Medical Officer of Health, and the patient shall not be removed from or leave the ship except with the consent in writing of the said Medical Officer. Persons suffering from suspicious illness may either be detained on board for a period not exceeding two days, or be taken to hospital and detained there for a like period for probation. No person on board an infected ship shall be allowed to land unless he satisfy the Medical Officer of Health as to his name, destination, and address, whereupon the Medical Officer shall forthwith transmit the name, etc., of each such person to the Clerk to the Local Authority, who in his turn shall transmit the same to the Local Authority of the District in which such intended place of destination is situated. Every such person who within 48 hours of landing shall arrive at any destination or address other than that given is bound upon arrival forthwith to notify in writing his destination and address to the Medical Officer of Health or to the Local Authority of the District in which his address is located. The Medical Officer of Health, in the case of every infected ship, shall direct all the necessary steps for disinfection and for prevention of spread of infection, and the master of the ship shall execute such directions. The master shall, in the event of any death from the named diseases taking place on board, either commit the body, properly loaded to prevent its rising, to the deep, or shall deliver it in charge of the Local Authority who shall lawfully and properly dispose of it; he shall cause all clothing, bedding, or other articles likely to retain infection which have been used by the infected person, to be disinfected or destroyed; he shall cause the ship and every article therein likely to be infected to be disinfected or destroyed, according to the directions of the Medical Officer of Health.

Where a ship is not certified to be infected, but has passengers on board who are in a filthy condition, or has come from a place infected with the named diseases, the Medical Officer of Health may certify accordingly, and shall give a duplicate copy thereof to the master of the ship, and retain the other or transmit it to the Local Authority. In such a case no person on board shall leave or be allowed to leave the ship until the names, intended place of destination, and intended address at such place have been given to the Medical Officer of Health.

Following upon this are the duties of Medical Officer of Health,

Clerk to the Local Authority, and of individuals, as have been previously detailed in the case of an infected ship.

If the Medical Officer of Health has reason to believe that any ship coming or being within the jurisdiction of the Local Authority is infected or has come from an infected place, he may direct that all bilge-water and water-ballast be pumped out in some suitable place before such ship enters any dock or basin, or if any danger be apprehended from such action, as for example, danger to stability of the vessel, he may cause any tank, etc., containing the water-ballast to be sealed and unopened so long as the ship remains within the jurisdiction of the Local Authority. He may also, where the Local Authority provides a proper supply of water for drinking and cooking purposes, direct that all casks or tanks on the ship which contain the water-supply thereof, shall be emptied, cleansed, and thereafter be replenished. The Regulations enact that a Local Authority may appoint one or more legally qualified practitioners to act in the execution of this order, either in place of or as an assistant or assistants to the Medical Officer of Health, and may pay such practitioners reasonable remuneration.

Port Sanitary Districts and Authorities. — While by virtue of section 177 of the Public Health (Scotland) Act, 1897, a local authority has control, for sanitary administration, over any ship which may lie in any river, harbour, or other water within the area of the local authority, or *ex adverso* such harbour, river, etc., and over any ship within three miles of the coast forming the boundary of the area of the local authority, further powers have been conferred upon a local authority or authorities as port sanitary authority upon the establishment of a Port Sanitary District. The Local Government Board may by Provisional Order constitute any local authority whose district or part of it forms a part of or abuts on any part of a port or the waters of such a port, or any persons having authority in or over such port or part of it, "port local authority." Such port local authority may be constituted by a single local authority, or by a joint authority of two or more local authorities having jurisdiction within the same area (where for example a navigable river forms the boundary line of two counties or burghs), or of representatives of two or more of said local authorities. On the institution of a port local authority by the Board by Order, said Order must be forthwith laid before Parliament. The powers conferred upon a port local authority are those which are embraced in the Public Health Acts as referable to houses, with reference to nuisances, structural alterations, as for ventilation of sleeping places, water storage, etc.

Up till the present time no port local authority has been constituted in Scotland, but Glasgow has made application to the Scottish Local Government Board to be so constituted for the Customs port of Glasgow, and evidence has been heard by the Commissioner appointed by the Board. Powers to do this were only conferred upon the Scottish Local Government Board in the Public Health (Scotland) Act, 1897, secs. 172–176, these having been enacted in like terms to those of the English Act of 1875, secs. 287–292. In England and Wales on the other hand, sixty Port authorities have been constituted, fifty-eight per-

manently, and two temporarily. In thirty-four of this total number the administration is vested in a single Local Authority, and in twenty-six in joint Boards.[1]

The essential duties of a port local authority may be comprehended under the following heads, viz. :—

(1) The institution regarding ships of all those measures which a Sanitary Authority may institute with regard to houses for the preservation of the health of their inmates, and for preventing the spread of infective diseases; (2) the exercise of the Powers conferred upon local authorities by the Cholera Orders, viz. : medical inspection of ships, their crews, and passengers with reference to detection of the diseases named in the Orders and of any other infective disease, the isolation of infective persons, the sanitary condition of the ship itself, the institution of the necessary measures of disinfection, and, generally, quarantine measures—all with the object of preventing infectious disease to be spread from ship to port populations, and thence throughout the country.

The duties of a port medical officer of health have been laid down by a General Order of the English Local Government Board of date June 19, 1893, and those of port inspector of nuisances, by an Order of date July 19, 1883.

Places for the Reception of Persons who have been exposed to Infection, and of Infective Persons.—In order to prevent the spread of infective diseases, the existence of which has been revealed by notification, the Public Health (Scotland) Act, 1897, provides for the establishment of : (*a*) Houses of Reception, and (*b*) Hospitals, the former of which are intended for those who have been exposed to infective disease, but who are not yet, and who may not be, attacked by the disease; the latter, for those who have been exposed and who already have contracted the disease. The law in Scotland respecting Reception houses will be found in the following sections of the above Act, in order of sequence, viz.: Sections 47 (sub-section 4); 54, 66 (sub-section 1); and 141. Their purpose will be better revealed, however, if these are discussed in a different order. Section 66 (1) is to the effect that any local authority may, and if required by the Local Government Board shall, provide, furnish, and maintain for the use of the inhabitants of their district suffering from infectious diseases, hospitals, temporary or permanent, and *houses of reception for convalescents from infectious diseases, or for persons who have been exposed to infection;* section 161 authorises a local authority to borrow monies for the above purposes; section 47, sub-section 4, gives the local authority power, when deemed necessary, to remove from any house or part thereof, or from any tenement of houses, all or any of the residents not being themselves sick, on account of the existence or recent existence therein of infectious disease, or for the purpose of disinfecting such house or part thereof, or such tenement or part thereof, when, after representation to a sheriff, magistrate, or justice, said sheriff, etc., on being satisfied of the necessity for such removal, shall grant the necessary warrant. The local authority is by this

[1] Reports and Papers on the Port and Riparian Sanitary Survey of England and Wales, 1893-94, issued by the Local Government Board, 1895.

section empowered to provide temporary shelter or house accommodation, and if necessary maintenance with any necessary attendance, free of charge, for such removed persons during the period of their removal. Section 54 deals with the removal to hospital of infected persons without proper lodging, and also enacts as an alternative measure that the magistrate may direct the removal from the room or house occupied by such persons of all others not in attendance on him, the local authority to provide suitable accommodation for such person or persons. Reception houses are thus obviously intended to act as one of the preventive measures against the spread of infective diseases, and may be reckoned as a necessary integral part of the sanitary equipment of a well-constituted local authority. Exposure to infection and impossibility of disinfection of the homes unless vacated are the gauges by which a local authority may test its powers of removal. Assuming that persons so exposed are removed, under what conditions are they to be treated? The object and intention of removal being to discover whether from such exposure the disease will develop in those exposed, it is therefore necessary to keep the persons under regulated observation for such periods as will overlap the incubation periods of the diseases to which they have been exposed. During the period of detention however, according to the present interpretation of the law, no control over the movements of those received, except of decency and order, can be exercised. Accordingly in certain populous places such persons are allowed to go about in public as they will, even to attend their employment.

There can be little doubt as to the advisability of conferring upon local authorities the powers of compulsory detention and isolation of such persons, with respect at least to certain of the infective diseases. Even with compulsory powers of isolation, reception houses should be so placed that a small area of surrounding land, for purposes of exercise and recreation of the inmates, should act as a zone of separation from the outside community; they should be placed on the outskirts of a town or city; the inmates should be medically inspected daily, and thermometric observations made twice daily: each house should possess an isolation room for the prompt isolation of any inmate who is attacked by a suspicious febrile illness, since in the absence of such provision the reception house would itself become an infected place within the meaning of the Act, and would thus expose the other inmates to a prolonged extension of the period of quarantine. Further, families who have been removed by reason of exposure to one infective disease should not be allowed, owing to the risks of new infection, to mix with other families who have been exposed to another infective disease, as is too often the case. In short, if reception houses are to form a really valuable factor in the prevention of spread of infective diseases, the regulations regarding them must largely be re-cast.[1]

[1] "Reception Houses." Paper by the Author, *Trans. San. Ass. of Scot.*, 1901.

CHAPTER XIII.

ISOLATION HOSPITALS.

By section 66 of the Public Health (Scotland) Act, 1897, any local authority may, and if required by the Board shall, provide, furnish, and maintain for the use of inhabitants of their district suffering from infectious disease, hospitals temporary or permanent. The English Act of 1875, sec. 131, makes the duty optional. By section 3, Isolation Hospitals Act, 1893 — Lord Thring's Act — a county council may provide or cause to be provided in any district within their county an isolation hospital or hospitals for the reception of patients suffering from infectious diseases. As alternatives to building such hospitals the Public Health Acts of both countries provide that a local authority may contract for the use of any such hospital or part thereof, may enter into any agreement with any person having the management of any such hospital or part thereof, on payments to be agreed upon, or may, in place of providing such hospitals, employ nurses to attend infected persons in their own homes, and also supply medicines and medical attendance for such persons.

Experience has abundantly demonstrated not only that without such hospitals no local authority can adequately cope with the repression of infective diseases, but that their institution has proved of the highest value.

The points to be considered in the establishment of an isolation hospital, when its erection has been determined, are briefly these, viz.: (1) size; (2) situation and site; (3) incidence of accommodation in respect of sex and diseases.

I. *Size.*—As a general proposition it may be held that hospitals should be of such a size as will provide at least one bed per thousand of population. But this ratio may be increased or diminished in the light of the capacity of a population to afford means of efficient home-isolation. It may be laid down as a general rule that in mixed populations chiefly composed of the working-class the ratio should be higher than the foregoing, and in well-to-do populations it may probably be somewhat lower. Glasgow for example, for a population of 760,000 (in round numbers), provides 950 beds. This ratio, however, is more difficult to determine in rural than in urban districts, and in the former especially, where the population is widely scattered. In county districts, the ratio must be determined by the above factors in the local problem, and the number of hospitals and the places where they are to be planted must be determined largely by the distances to be traversed by the removed patients. Hitherto, this has been met during panic, and in face of marked outbreaks of disease, by the

erection of temporary wooden structures, most of which however are unsuitable, and never can be of the utility of more substantial

FIG. 225.—This figure shows the distribution of the buildings. At the main gateway is the Inquiry Office. On the right of the main entrance-way is the Small-pox Hospital, which is separated from the other parts of the Hospital by a high wall, and which has a separate entrance, shown among the trees in the lower corner of the figure. The Administrative Block is between the Small-pox Hospital and the river Clyde. On the left of the main entrance-way are the Fever Blocks. At the upper left corner is the Disinfection and Laundry Department.

buildings. While isolation hospitals are intended for infectious diseases, experience has demonstrated the peril of treating small-pox

cases alongside others of other infective diseases. Consequently it works out in practice that a special hospital for this disease must be provided, in addition to the ordinary isolation hospital. In these days small-pox is a more likely disease in a populous place than in a rural neighbourhood, but the recent serious recrudescences of the disease point to the need for the provision of accommodation against its possible outbreak even in rural communities. In view, however, of its infrequency in such neighbourhoods, it would be too much to demand of county local authorities that they should build, furnish, and equip a permanent hospital to be devoted solely to the treatment of small-pox, but it would be reasonable to ask that local authorities should provide their districts with portable hospitals and with prepared sites, so that hospital accommodation for this disease could be instituted within twenty-four hours. Recent improvements in the construction of portable hospitals in fitting parts enables this to be rapidly and efficiently done, and with every prospect of comfort to inmates.

II. *Situation and Site.*—To serve the needs of a populous community and in order to minimise the risks of removal, an isolation hospital should be situated within comparatively easy reach of the centre of population whose needs it is to supply, and yet must be sufficiently removed to overcome reasonable objections, such as nearness to inhabited houses and possible risks of infection to the occupants thereof. No local authority is entitled to plant a hospital in such a position as will prove a nuisance either in common law or in public health law, or will produce injury to the rights of the owners of adjoining property by causing a nuisance. Lord Blackburn laid down the rule of law on this point in an English appeal case—Metropolitan Asylum District *v.* Hill [1] :—"To put together," he said, "in one spot patients suffering from infectious disease is lawful, but it must be made under such guards as not to endanger the public health by communicating this infectious disease; and, as it seems to me, so as not to produce injury to the rights of owners of adjoining property by producing a nuisance to it." The outskirts of a city, therefore, are indicated generally as the situations which ought to be chosen for erection of a hospital, since there is the greater likelihood of securing a more open site, and consequently, unconfined air-space. The propinquity of an isolation hospital to dwelling-houses, or of wards for infective diseases to non-infected persons in ordinary wards in a hospital, has been proved to be prejudicial to the inhabitants or occupants. The late Sir Richard Thorne Thorne demonstrated this in the case of the Children's Hospital at Pendlebury—an excellent modern hospital—in which the main hospital is devoted to the treatment of the ordinary diseases of childhood, and a separate pavilion to the treatment of infective diseases. He showed that children in the ordinary wards contracted diseases apparently from the infective pavilion. The truth of this fact has been probably more clearly demonstrated, however, with respect to small-pox. In Power's report upon the incidence of small-pox in the vicinity of Fulham Hospital, he pointed out that the disease was evidently transmitted by the medium of the atmosphere

[1] 6 App. Cas., 193; 44 *Law Times* (N.S.), p. 653.

Ruchill Hospital, Block Plan.

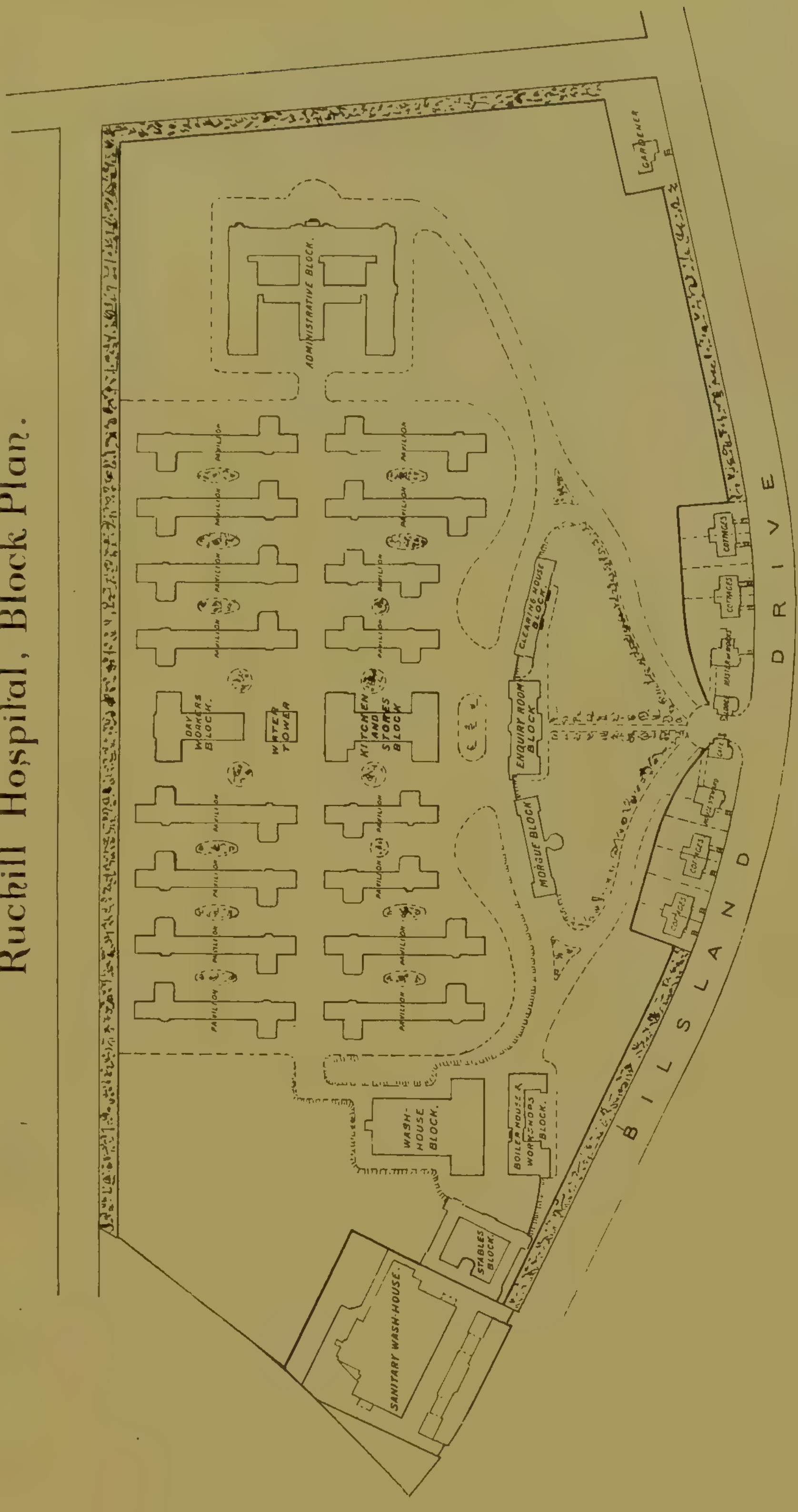

FIG. 226.—The illustration is self-explanatory.

to occupants of houses situated some distance from the Hospital, that the incidence in number of cases diminished directly as the distance, and that the convection of the disease could not be attributed to lines of traffic. In respect of the hospital at Sheffield, Barry found a like incidence of disease, but the element of the possibility of personal convection could not be eliminated from the problem. Efforts have been made by different writers to whittle down these facts, but careful investigation of the facts of these cases and of others points to the correctness of the conclusions reached. Accepting this view, the English Local Government Board have advised that a local authority should not contemplate the erection of a small-pox hospital on any site where, within a quarter of a mile of it as a centre, there exists any hospital, work-house, large school, or other establishment, or a population of 150 to 200 persons, or on any site where within half a mile of it as a centre, there exists a population of 500 to 600 persons, whether in institutions or in dwelling-houses. To avoid any risk of aerial transmission of infection, both English and Scottish Local Government Boards demand that no building which is a constituent part of an ordinary isolation hospital shall be nearer than *forty* feet to the boundary wall, and that each block should be separated from the others by a like distance; and further, that said boundary wall should not be less than $6\frac{1}{2}$ feet in height. In respect to small-pox a larger separating zone is necessary, viz.: from 120 to 150 feet.

The site chosen, while to some extent dependent upon local circumstances, ought to combine as far as possible the following conditions, viz.: (1) a porous subsoil; (2) a gentle sloping ground surface; and (3) an exposure protected from the east and north, and open to the south and west. Such conditions, accompanying abundance of good water and pure air, will go far to contribute to the healthiness of the hospital.

The area of the site ought to bear a direct relation to the proposed number of beds. The Local Government Board of England in this respect suggests eight beds per acre. Hitherto this has been seldom realised. The maximum, however, ought not to exceed twenty beds per acre. If a few well-known hospitals be taken at random, it will be found that the Belvidere Hospital has thirteen beds, and Ruchill Hospital (both of Glasgow), twelve beds per acre; that at Heathcote, Leamington, eleven beds; Ealing, twelve beds; Sheffield, forty-eight beds; Dunfermline, fourteen and a half beds; Willesden, six beds; and Bristol (at present), about four beds per acre.

Incidence of Accommodation.—In rural hospitals, facilities must be provided for the treatment of at least three different diseases at the same time; in urban communities, the facilities must be extended much beyond this. In respect of the latter indeed, provision must be made for the reception and separation of each of the diseases scheduled in the Notification Act, for although the whole of these diseases may not be coexistent, it generally happens that there is an excess of cases from one or more of the infective diseases sufficient to occupy the spare space. The accommodation must be duplicated for the sexes. The total number of beds to be provided will be regulated

by the number of population for the needs of which the hospital is to be erected.

An isolation hospital of any pretensions ought to include the following different buildings suitable for their different uses, viz. :—

1. An administrative block for hospital staff, dispensary, stores, etc.;
2. Wards for the treatment of different diseases during acute illness and during convalescence, for the separation of the sexes, and for probation of doubtful and separation of non-infective cases;
3. Accessory buildings, which should include, laundry, wash-house, disinfecting apparatus, stables, heating apparatus, mortuary, offices, and inquiry room. (*Vide* figs. 225–226.)

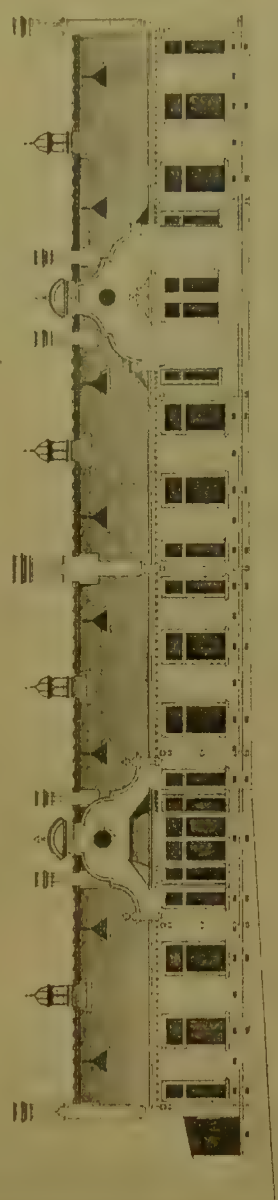

FIG. 227.—Elevation Plan of a Large Ward in Ruchill Hospital.

I. *The Administrative Department.*—Little need be said on this point, except that this department should provide commodious space for resident physicians, nurses, and others on the resident staff, and that it should occupy a central or convenient position relative to the different working parts of the hospital. It will depend upon the amount of work to be done and upon the importance of the hospital whether or not operating theatres should also be provided, and in addition, a bacteriological laboratory for research, verification of diagnosis, and the study of the effects of serum treatment. In view of the importance of the bacteriological diagnosis of doubtful

throat cases, of infective pneumonia, and of blood-reactions in enteric fever and other diseases, every well-equipped isolation hospital should possess such a laboratory.

II. *Wards.*—Isolation hospitals are now most commonly built of the pavilion type and of one storey in height. This system of planning was first advocated by Tollet, a French architect, about the middle of last century. When viewed from every point, such a type of hospital is probably the best. The chief objection to it consists in the large area of land required for its setting, a desideratum which is sometimes most difficult to obtain at any cost, and, always, even if obtainable, at enhanced cost, in the neighbourhood of populous places. From time to time the question has been raised, whether or not it is quite possible to construct an efficient isolation hospital on other than the pavilion type. Obviously, if an affirmative answer were forthcoming, much trouble and expense would be saved to urban local authorities. The answer to this question depends upon a variety of factors, chief of which are probably the following, viz.: likelihood of convection of contagium from one ward to another, conditions of light and ventilation, service, and administration. It is necessary, therefore, to discuss the merits and demerits of types of hospital construction.

FIG. 228.—End Elevation Plan of a Ward, Ruchill Hospital, Glasgow.

The advantages of the pavilion type are: (1) that each unit is separated from the rest, and even where there is an existing corridor, opposite windows therein permit of cross ventilation; (2) that each ward or unit is lighted from both sides, and therefore may also be ventilated by cross ventilation; (3) where the wards have been properly planned, the maximum amount of sunshine may be obtained; (4) patients can be more easily classified and sorted out; and (5) the administration is easy, as there are no stairs to climb and no long corridors, although against that must be put the distance to be covered by the staff from the administrative block. Thus are secured good ventilation, maximum sunlight, classification of patients, and the minimum of trouble in administration. The main and perhaps the only objection which may be urged against their use is their great initial cost with relation to the number of patients treated. While eight beds per acre is the ideal of the English Local Government

Board, there can no harm ensue if the number of beds is at least double or more than double that figure, provided that efficient ventilation and other factors prevail. It has with much reason been urged that the pavilion type may be adopted, but that the building should be of more than one storey. To this it has been objected that administration is difficult; but modern lifts are after all movable stairways, and these economise time and labour. Another objection is risk of fire. This, doubtless, is a question deserving of every consideration, but it is a contingency, viewed in the light of past experience, which should not be allowed to bulk too largely In such a type of building ground space would be economised, and by architectural ingenuity efficient isolation may be secured. While the unit ward of a one-storied pavilion is thus rectangular in shape, and possesses windows on each side, a two-storied or three-storied building on this principle would but duplicate or triplicate the essential conditions named, and would adequately meet the case, provided that each pavilion block

FIG. 229.—Cross-Section Plan of Ward in Belvidere Fever Hospital, Glasgow.

were sufficiently far separated from its neighbours that neither free movement of air nor admission of sunlight would be obstructed. At the same time such blocks might be united at right angles to their length by a connecting corridor, covered above but open on the sides, like the connecting bar of the letter H. A hospital constructed of circular wards, however, would so far meet the conditions of the pavilion type.

The second type of hospital may be called the *Block type*, where the buildings are separated in blocks, and thus each block becomes practically a separate hospital having a separate entrance with a central staircase, from the landings of which would pass the wards which are rectangular in shape, and which would or would not possess windows on each side. This is a favourite Continental method of constructing hospitals; but to be efficient the system requires considerable land, and administration is difficult.

Another type is the *Corridor* Hospital, in which there is a central corridor from which pass the wards which lie parallel to the line of corridor. The objection to this type is that there is no cross-

ventilation, because the windows are only on one side of the room, although the beds are upon both. In such cases, one set of patients look out upon the sky, and the other upon the wall separating the ward from the corridor. In such a ward effective isolation is impracticable although administration is easy, and ventilation by natural means can hardly be efficient; besides, the entrance of sunshine is necessarily much more limited. So long, however, as the need for an abundant and pure supply of air and of as much sunshine as is possible are important factors in the treatment of all diseases, and more especially, of infective diseases, so long will architectural methods require to conform to the type of building in which these are best and most easily secured, and that type is to our mind the pavilion type, although not necessarily a one-storied building. Exigencies of space, economy, and other considerations may sometimes compel the erection of two-storied pavilions, but where cost of land is an unimportant item the ideal isolation ward is a one-storied building of the pavilion type. One pavilion ought to be distant not less than from 40 to 60 feet from those adjacent, the precise distance depending upon the height of the pavilion. In the opinion of some, each pavilion should be connected with the rest by connecting corridors, which should consist merely of covered ways entirely open at the sides. In our view such are neither necessary nor advisable.

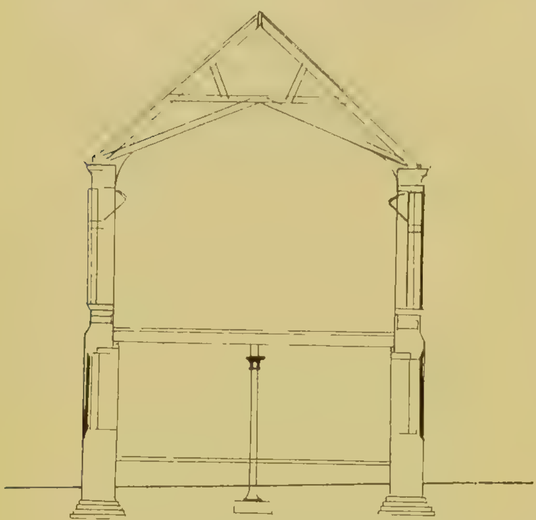

FIG. 230.—Cross Section of Ward in Ruchill Hospital.

Should the small-pox department be included within the general hospital area it ought to be separated by a high boundary wall in addition to the sanitary zone of 150 feet already mentioned. Compatible with reasonable economy too, the small-pox pavilions ought to be separated further from each other than in the case of pavilions for the other infective diseases.

Another type of hospital, however, has been devised by Henman, which has in fact been constructed in the Belfast Royal Victoria Hospital. The principles of its construction were intended to overcome the administrative difficulties of the single-storey pavilion type, which, covering of necessity a large area of ground, causes the staff to traverse considerable distances from the administrative block. This, it was believed, could be overcome by spreading out one-storey wards side by side, and by lighting them with lantern lights. By this arrangement the area of work to be supervised would be concentrated, corridor communication would be minimised, there would be no stairways or lifts as in the block or corridor systems, and abundant ventilation could be secured by mechanical methods. In the

Belfast Hospital these views have been reduced to practice, and the novelty of the plan is that wards and accessory rooms are placed side by side with no space between. All these rooms are on one floor level practically under one roof, are entered by short corridors which open from a main corridor running at right angles to the lengths of the wards. Being a general hospital, there are medical, surgical, and other wards, and being in conjunction with a medical school, there is a large "extern" department, a pathological department, and a lecture theatre all on the same level. The administrative block, which consists of four storeys, is on the north side of the main corridor. The axis of the wards is almost north and south. At the south end of each ward is a large window opening out upon a covered balcony, and from the window the view is extensive. Along the roofs of the wards are placed lantern lights so that sunlight may freely enter. The whole building is ventilated by the "plenum" system, the air being conveyed by ducts which are accessible for cleaning. The air-supply is ten million cubic feet hourly, which is equal to a total change of air ten times hourly night and day throughout the entire wards. In the opinion of the architect there need be no risk of the spread of infection in a hospital so planned, since each ward is separately supplied with fresh air, and the foul air from each ward is independently discharged. In the discussion which followed the reading of the paper in which the plan of this hospital was fully described, the question of efficiency of lighting was raised, and a representative from Belfast stated that the building was not only well lighted, but from the position of the hospital had also a cheerful outlook.[1]

Ward-Space.—The cubic and superficial spaces to be allotted per bed ought to be considerably greater than those in a general hospital, on the principle that free dilution with fresh air diminishes the virulency of infective matter. The minimum cubic space should not be less than 2000 feet; a still more desirable amount is 2500 feet. The minimum floor-space should at least be 144 square feet, and, if possible, 180 square feet. These minimum conditions are secured in a ward of the following dimensions, viz.: 24 feet wide, 14 feet high, with 12 feet of wall-space per bed; the larger requirements in one which measures 26 feet in width, 14 feet in height, with 14 feet of wall-space per bed. In some modern hospitals, as Bristol, the cubic space per patient is 2800 feet, and the superficial space 180 square feet.

Lighting.—Plentiful light is a prime essential of every hospital, but more especially of isolation hospitals, by reason that light, and more particularly sunlight, is one of the best natural germicides. Window-space should therefore have a distinct relation to total cubic space of a ward, and the proportion between the former and the latter should not be more than one square foot of window space to forty cubic feet of the latter, and should not be less than one to seventy. Unless special measures be taken for the conservation of heat, the ratio of one to forty-five makes the heating of a ward difficult. This, however, may be overcome by having double window casements, or double glazed plate-glass windows. In temporary wooden hospitals, even with a ratio of one to seventy it is practically

[1] *Jour. San. Inst.*, vol. xx. Part iv. p. 599.

impossible to sustain sufficient temperatures, unless the walls are double and the interspace is filled with such a non-conductor as sawdust.

Heating.—Hospitals are usually heated: (1) by hot-water pipes at ordinary pressure; (2) by open fires; or (3) by a combination of both. Where a hot-water system is to be installed, the engineer must carefully calculate the extent of piping necessary, according to the general rules which have been already explained.

Ventilation.—In many hospitals, heating and ventilation are combined, whereas in others provision is only made for the entrance of fresh air at the outside temperature, or by passing the incoming air over a heated surface of pipes. There can be no doubt that the best means to obtain efficient ventilation is to purify, warm, and impel fresh air into the wards of a hospital, since by previous warming the air can be introduced at a greater velocity with comfort and safety. This is particularly of moment in convalescent wards. Another mode is to warm the incoming cold air by passing it over hot-water pipes, and to exhaust the foul air by the ward chimneys, or by special exhaust flues built around or alongside the smoke flues, and by roof-ridge fixed ventilators. A third mode is to permit the air to enter by Sheringham valves or Tobin's tubes, aided if necessary by cross-window ventilation when required, and to leave the heating to the hot-water piping and the ward fires. The recent tendency in the building of new hospitals to combine a scheme of heating and ventilation is unquestionably in the right direction, and probably the Key system is the best at present, the principles of which have been already explained. The advantages which this system possesses are that purified warmed air may be impelled at uniform velocity into the wards in cold weather, and purified cooled air in warm weather, and also that the supply of such air is constant.

One of the principal objects in securing that an isolation hospital should be surrounded by a free open space is that the micro-organisms which pass into the air from infective wards may be destroyed by the action of freely diluted air. It has however been deemed advisable in certain places as Nottingham, Bradford, Blackburn, and others, to subject the outgoing air from such hospitals to the influence of the heat of a furnace. In the Western Fever Hospital, London, such an apparatus has been installed to extract and purify the air of two wards. These, however, are mainly intended to act as the motive power in a vacuum system of ventilation, although at the same time they purify the out-going air. In Barry's Report on this subject to the Local Government Board of England much interesting information will be found. More recently, however, Henman has conceived the idea of filtering the exit air from hospitals by the moist screen used for the inlet air in Key's system, but applied to the outlets and on a smaller scale. He proposes that in the outlet at the head of each bed in the ward a small screen should be placed, which might, if thought advisable, be moistened automatically with a disinfecting fluid.[1] Whether however this proposal will go further than the experimental stage, in which it now is, remains to be seen. But after this comes the question,

[1] *Jour. San. Inst.*, vol. xv. Part iv. p. 641.

Is it necessary? For there is little evidence, except in small-pox, to show that isolation hospitals constructed in conformity to legal requirements are a source of infection to the surrounding population.

Typical Isolation Hospitals.—The following may be taken as typical isolation hospitals on the large and small scale for an urban

FIG. 231.—City of Glasgow Hospitals, Belvidere. Block Plan. This plan shows the disposition of different parts of the Hospital. If a line be drawn through the centre of the figure from top to bottom, and a second, at right angles, through the centre, the buildings devoted to the Fever Hospital will be seen to occupy the two quadrants to the right, and the lower quadrant to the left. The Small-pox Hospital occupies the upper left quadrant, and is separated from the other buildings by a surrounding, high, brick wall.

and a rural community respectively. They have been selected because they are excellent types, and because they have been constructed to meet the most modern requirements. These are Belvidere and Ruchill Hospitals, Glasgow, the New Fever Hospital, Edinburgh, the Dunfermline Combination Hospital, and the Lanarkshire Middle Ward, Motherwell.

Ruchill Hospital is situated in the northern outskirts of the

city, of easy access by road and rail, and, planted upon a rising ground, it provides accommodation for over 400 beds. It is composed of the following blocks, viz.: (1) administrative; (2) isolation wards; (3) inquiry; (4) wash-houses and disinfecting; (5) kitchen and stores; (6) day workers' block; (7) clearing-house and fire-engine

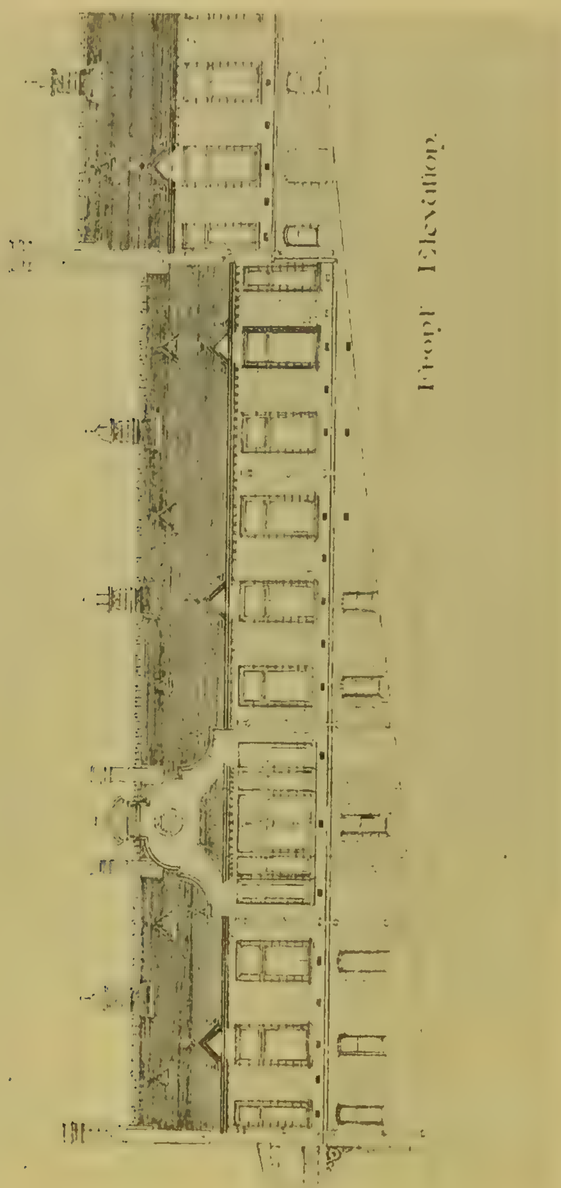

FIG. 232.—Front Elevation of a Ward in Ruchill Hospital, Glasgow. At the extreme left of the Figure, abutting on the end of the ward, will be seen a conservatory for the use of convalescents.

station; (8) morgue; (9) boiler-house and workshops; (10) stables; (11) cottages for principal non-professional officials. (Fig. 226.)

The isolation pavilions number sixteen in all, twelve large, and four small. At the sunny end of each a balcony or verandah for convalescents is a prominent feature. Each large pavilion embraces two acute and two convalescent wards, the former for ten beds each, the latter for five beds each. The dimensions of a ward for acute

cases are as follow: length, 66 feet; breadth, 22 feet; height, $15\frac{3}{4}$ feet; total superficies of floor, 1452 square feet; total cubic space, 23,100 cubic feet; window space, 391 square feet; ratio of window space to total cubic space, about 1 to 60. The dimensions of a ward for convalescent cases are exactly the same as for a small pavilion convalescent ward, as enumerated below. Each small pavilion contains two acute wards, and two convalescent wards. The dimensions of each ward in a small pavilion are these: length, 33 feet; breadth, 22 feet; height, $15\frac{3}{4}$ feet; total superficies of floor, 726 square feet; total cubic space, 11,550 cubic feet; window space ratio (in acute ward), 1 to 62, and (in convalescent ward), 1 to 45. The total number of beds in the hospital amounts to 408. From the foregoing figures, it

FIG. 233.—End Elevation of Ward, Ruchill Hospital.

will be seen that each patient receives 144 square feet of floor-space and 2300 cubic feet of air-space.

The ground-floor plan (Fig. 235) of a small pavilion shows the following accommodation, viz.: four wards with five beds each, two nurses' rooms, two pantries, two bath-rooms, two lavatories and water-closets for patients, like accommodation for those on duty, two steep-rooms for soiled linen, etc. The wards are disconnected from the annexes which contain the sanitary fittings by a hall having opposite doorways into the outer air, and the nurses' rooms and pantries are situated between each pair of wards.

A like plan of a large pavilion shows a similar disposition of arrangements, but on a correspondingly larger scale.

All angles in the inner walls of ward are rounded off in Parian cement, so as to prevent lodgment of microbic dust, and for easier cleansing.

The heating of the wards is effected by hot-water pipes at ordinary

pressure, aided by open central ward fires. Ventilation is accomplished by fixed roof-ridge cowls, hopper-sashed windows, and by concentric outlet air-shafts placed round ward flues, the entrance of fresh air being effected by the windows which are provided as above, but which, also, are constructed with movable sashes.

FIG. 234.—Ward of Ruchill Hospital.

This hospital is entirely devoted to the treatment of infective diseases other than small-pox, for the treatment of which ample provision exists in another hospital.

New Fever Hospital, Edinburgh.—This new hospital, which has been planned to include the most modern requirements of an isolation hospital, is located upon the estate of Colinton, on the southern outskirts of the city, occupies about 40 acres of land, and provides for the accommodation of 600 patients. The population of Edinburgh being about 300,000, the ratio of beds per 1000 of population is therefore 2 per 1000. The number of patients per acre is fifteen. The site of the

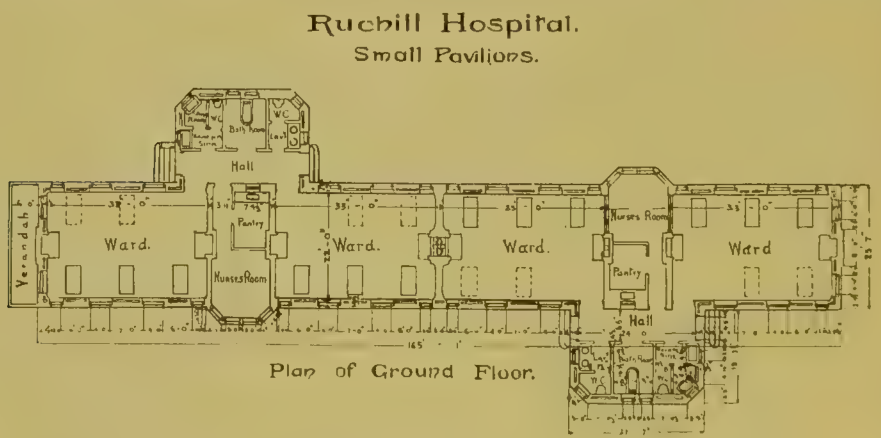

FIG. 235.

hospital, which has a gentle southern slope, is about 400 feet above sea-level, and is freely open all around, especially on the south, east, and west. It is intended to permanently place the small-pox hospital upon

this area of land, but at a satisfactory distance from the general isolation wards. The land is plotted out in buildings as follows: The main entrance is from the north, the buildings looking north and south. Facing the entrance but further within it, and occupying a nearly central position in the grounds, are the following blocks, viz.: (1) general offices; (2) buildings for stores, kitchen, and dining-room; (3) nurses' and servants' homes. To right and left of these the ward pavilions are arranged, those on the left being entirely devoted to scarlet fever, while those on the right are set apart for diphtheria, enteric fever, erysipelas, measles, chicken-pox, whooping-cough, and typhus fever. The reception and observation wards are situated on either side of the main entrance, between it and the ward blocks, and the isolation wards for complicated cases, toward the further extremities of the respective ward-groups. At the north-east corner of the ground are: (*a*) ambulance station; (*b*) lecture-rooms; (*c*) pathological laboratory; (*d*) museum and mortuary; and at the south-east corner (*a*) laundry and wash-houses; (*b*) disinfector, boilers, and incinerator. In the south-east corner, standing by itself, is the ward for typhus fever.

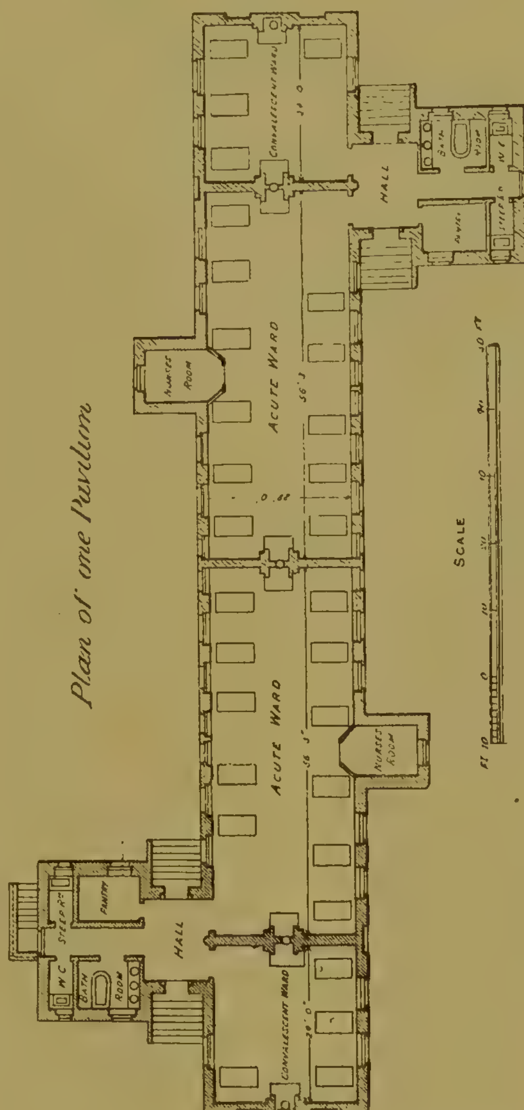

FIG. 236.—Ground Plan of a Pavilion in Belvidere Hospital.

Provision has been made for the treatment of the diseases named above, and the incidence of bed accommodation for these different diseases is shown in the following Table.

Table XXII.

Ward Accommodation and Beds.

Diseases.	Pavilions. Blocks.	Beds. In each Pavilion.	Beds. In each Class of Pavilion.	Totals for each Disease.
Scarlet Fever—				
Observation	1	4	4	
Ordinary	6	46	276	
Convalescent	1	24	24	
Isolation	4	4	16	
				320
Enteric Fever—				
Observation	1	4	4	4
Ordinary	2	38	76	
Isolation	1	4	4	
				80
Typhus Fever	1	10	10	10
Diphtheria	1	30	30	30
Measles—				
Ordinary	2	38	76	
Isolation	1	4	4	
				80
Chicken-pox	1	19	19	19
Whooping-cough	1	19	19	19
Erysipelas	1	30	30	30
Probationary	2	4	8	8
		Total Number of Beds		600

Between the ward pavilions, which are two-storied and whose axis lies north and south, there is ample space for recreation, which, however, is further provided for in other parts of the grounds.

Besides the general wards, each pavilion has on each floor a two-bed and a single-bed ward for special or private cases.

The walls of the wards are composed of Keene's or Parian cement, with rounded hollows at re-entrant angles.

Heating of wards is effected by ventilating steam-coils and by ventilating stoves, and in the smaller wards by ventilating grates. Cross ventilation by opposite windows is the chief means of ventilation of wards. By means of covered ways the staff may pass protected from the weather from the administrative department to the pavilion blocks. These ways, although roofed, are largely open on the sides. This covered way does not extend, however, to the typhus fever ward, which is of one floor only, the walls of the ward being raised on built piers, so that air may freely circulate below the building.

TABLE XXIII.

Spaces Allowed per Bed.

Disease.	Cubic Space per Bed.	Superficial Space per Bed.
Scarlet Fever	2000	156
Whooping-cough / Chicken-pox	1690	130
Diphtheria	2545	195
Enteric Fever	2514	194
Measles	1690	130
Typhus Fever	3042	254
Erysipelas	2028	156

From the foregoing Table it will be seen that both cubic and floor space have been regulated and fixed by the ages of the likely occupants, and by the character of the infectivity of each disease.

A very excellent type of a rural hospital is the Dunfermline Combination Isolation Hospital. It occupies a site the area of which is $2\frac{1}{2}$ acres with a southern exposure, and with a good fall for drainage.

The hospital consists of a central administrative building which is flanked by two semi-detached "quarantine" wards for the reception of doubtful cases. Behind this block, and on each side—west and east—is an isolation pavilion, which is from 40 to 60 feet distant from the administrative block. These pavilions are connected with the administrative block by means of open covered ways. The offices are placed in the extreme west angle of the site, between which and the western pavilion sufficient space has been left whereupon to build another pavilion, if and when such extension is required. In the lower right angle of the site it is proposed to erect accommodation for the principal officials.

A sanitary zone of 40 feet separates at all points the buildings from the public road.

The fever pavilions are situated north and south. They are simple in design, being founded largely upon the plan of the Warrington Fever Hospital, and are so arranged that each window of the ward may receive the rays of the sun during several hours of the day.

The administrative building, placed on the southern side of the site, contains kitchen, store-rooms, rooms for physician and matron on the ground floor, and three large bedrooms, with bath-room and napery stores upstairs, while in the basement the air-warming chamber, air-propelling fan, and steam-engine for driving the fan are located. The probationary or "quarantine" wards, although they flank the former building, are wholly isolated from it and from each other. They may be overlooked, however, from air-tight windows from the administrative building. They are entered by separate doorways outside of the administrative block. Each ward—one for each sex—measures 24 feet long, 12 feet broad, and $14\frac{1}{2}$ feet high, and thus contains 4176 cubic feet of air-space. Each is intended for

two beds, so that each occupant has allotted to him over 2000 cubic feet of air-space, 12 feet of wall-space, and 144 square feet of floor-space.

Each isolation block contains one ward for males, and one for females. Each ward, on either side of the administrative block, has six beds, while those in the block behind, being smaller than the others, have only four beds. The latter are intended for convalescent patients when

FIG. 237.

circumstances are suitable. In each of these wards, the measurements provide the following spaces per bed, viz. : 2000 cubic feet of air-space, 144 square feet of floor-space, and 12 feet of wall-space. The present total number of beds is 36 ; the number of beds per acre is therefore about fourteen.

All the outer walls of the hospital wards are of hollow formation, the inner layer being of brick finished in adamant plaster, the outer

of stone, with an intervening air-space of three inches. All the corners in the walls, floor, and ceiling are rounded, so as to prevent lodgment of dust. Woodwork has been as sparingly used as possible because of its absorptive properties, and had objections not been offered by the Local Government Board, the floor would have been laid in granolithic instead of wood.

The offices consist of a wash-house, laundry, ambulance shed, mortuary, and a small disinfecting chamber for the use of sulphurous acid gas. Disinfection by heat is also provided for in a separate apartment by a Washington-Lyon disinfector of the type formerly described.

The heating and ventilation of the whole hospital are combined in one scheme, viz.: by Key's *plenum* system. The air of the administrative block is changed six times, and of the isolation pavilions eight times per hour day and night, and the system is guaranteed to supply air at a uniform temperature of 62° F.

The drainage system is excellent. The drain pipes are laid in straight lines, are of as small size as is necessary, and are provided with man-holes and inspection openings at all angles and junctions. The drains of each block of buildings are entirely disconnected from one another and from the main drain by ventilating traps, while the main drain itself is ventilated by the exhaust power of the heated air of the chimney-stalk at the offices, by which a current of fresh air with a velocity of 700 feet per minute is passed through the drain.

The Motherwell Hospital (Fig. 238) stands on an elevated site overlooking the Clyde valley and comprises six acres of ground. It has been planned for 100 adult patients in the following pavilions, viz.: four pavilions of 20 beds each, with eight private wards of one bed each; one isolation pavilion of 6 beds; and one observation pavilion of 6 beds. The buildings are plotted out on the site in the following manner. At the entrance lodge are situated a waiting-room for the use of patients' friends, and the inquiry room. The administrative block occupies a detached position in front of the hospital site, and the kitchen and service department a central and convenient position for distribution of food.

The four main pavilions are built with their axis north and south, thereby permitting of the fullest amount of available sunlight. Each pavilion is divided into two wards of 10 beds each, and has two separation-wards of one bed each attached. The nurse's room is placed between the wards in such a position that by means of windows she can overlook both the main and separation wards. Each main ward has the following dimensions, viz.: length, 60 feet, breadth, 26 feet, height 13 feet. The total gross cubic space is therefore 20,280 cubic feet, and the total superficies or floor-space, 1560 square feet; thus each patient is allowed 2028 cubic feet, 156 square feet, and 12 feet linear wall space. All internal wall-angles of wood and plaster-work are rounded or hollowed for easier cleaning. All the walls of the wards are faced externally with stone, lined on the inside with brick, a hollow space intervening for ventilation. The lathing of walls and ceiling is composed of steel. The lighting of the wards is accomplished by means of windows which extend from

$2\frac{1}{2}$ feet from the floor to the ceiling. These are constructed of double-hung sashes to three-fourths of the height, with a hinged hopper fanlight at the top which opens inwards. All the ward windows are double-glazed with sheet glass. There is a window between each bed. At the southern end of each pavilion there is a verandah for the use of convalescent patients. Attached to each pavilion is a suite of undressing, bathing, and dressing-rooms through which patients have to pass for toilet purposes on admission to and dismission from the hospital.

The wards are heated by means of (*a*) open fireplaces and (*b*) low-pressure hot-water piping. The latter is placed under the floor, and

FIG. 238.—This Hospital contains 100 beds for Infective Diseases. At the entrance is the Porter's Lodge, and adjacent to it is (2) Administrative Block. Behind and to the left is the block containing Laundry, Mortuary, Destructor, and Disinfecting Apparatus. Ranging along the back are Four Main Ward Pavilions, which are situated north and south, at the south end of which is a Verandah for convalescents. The two first Pavilions facing the reader are Isolation and Observation Pavilions. The site of the Hospital extends to about six acres, and occupies an elevated position.

from these pipes by branches radiators in the wards are supplied. These radiators are placed against the external walls under each alternate window, and two circular radiators are fixed in the centre of the ward to secure equalisation of temperature. The ventilation of the wards is achieved by means of the hopper fanlights of the windows, and the double-hung sash windows themselves. The window-radiators act in combination with fresh air inlets regulated by valves, and thus warmed air is admitted. The exhaustion of foul air is attained by putting vertical exhaust shafts in the end walls and Honeyman's ventilators in the ceilings. Each of these vertical shafts is fitted with a steam coil to ensure the upward movement of air.

The drainage arrangements are constructed on the separate system—one set of pipes carries away rain and surface-water, another

set the sewage. The drains are laid in practically straight lines, with inspection man-holes at connections, and with necessary traps and ventilators. The sewage is purified before leaving the grounds of the hospital by means of tanks and filters which can be worked continuously or intermittently, with or without the use of chemicals, and in such a way as provides for aëration of the filters. All hospital waste, kitchen refuse, bedding, or other infected material which is to be got rid of, is burned in a destructor also erected within the grounds. Disinfection is accomplished in a non-jacketed Disinfector, made by Messrs. Goddard, Massey, and Warner.

The mortuary is so arranged that through a fixed window relatives may look upon the faces of their dead.

Another commendable feature of this hospital is the provision of a complete system of subways connecting the various buildings. In these are located steam and water mains, wires for electric light, telephone, etc., and workmen are able to pass through them from one point to another of the hospital, thus making it unnecessary for them to enter an infected ward for examination of fittings or repairs.

The total cost of the hospital, including fittings, apparatus, machinery, furniture, etc., was about £37,000, or £370 per bed.

It will therefore be apparent that the hospitals described exhibit all the important modern improvements in construction, with some points of novelty in each case, and may therefore be taken as most illustrative of the most advanced types.

CHAPTER XIV.

DISEASES OF OCCUPATIONS.

Effects of Occupation on Health. — Of the many factors the sum of which determines the condition of health and longevity of man, perhaps none is so potent as that of his daily occupation. This is as true of man as an individual as of man in the mass. The evil effects of occupation arise very largely from the grouping of workers under entirely artificial conditions in factories, yards, and workshops. Coupled with artificial environment are the high pressure and competition of the labour market, which act as a contributory strain on workmen, especially upon those who are engaged in contract work or "piece" work, in which the wages are determined not by the time occupied in the work, but by the products which the workman can finish in a given time.

Centralisation of population in towns and cities due to the attraction of higher wages and outlets for employment for families and centralisation of labour have mutually interacted upon each other to assist in producing results inimical to the health of the employed. These effects have been appreciated by the Legislature in the Factories and Workshops, the Dangerous Trades, and other Acts in which the young and the female sex are so far protected against protracted hours of labour, and against accidents by machinery, and in which also the health of employees is conserved by compulsory sanitary conditions of workshops and factories. This is especially true of productive industries in which the commodity is made out of the raw material. Practically no change is apparent in primitive occupations, as farming, fishing, etc., except in the former of the more extended use of labour-saving machinery, since these callings must of necessity be followed in the open air; and although in these the conditions of employment generally are more conducive to health, they have at the same time attendant hardships and disabilities which are productive of disease.

It has been computed that there are about 12,000 different occupations. This large number is doubtless due in large measure to the great subdivision of labour which has become the characteristic feature of employment during the past half-century.

All occupations may however be divided into three great classes, if we adopt as the means of classification the bodily powers which are chiefly involved therein, viz. : (1) those in which the nervous system is most employed; (2) those in which the muscular system; and (3) those in which both in varying grades of combination are called into play. To the first class belong brain-workers generally, as authors, composers, teachers, and professional men; to the second, the "hewers of

wood and drawers of water," as labourers, navvies, quay-porters, and others of like classes; and to the third, all classes of workmen who unite skill with handicraft in their occupation, and in varying degree. It would probably be correct to say that the largest proportion of the army of the employed belongs to this last class.

But another subdivision may be adopted, viz.: with relation to the harmful effects which are produced by, or are incidental to, occupations. Ogle gives an excellent working classification on this basis. He divides occupations as follows:—

I. Where the workman adopts a cramped or constrained attitude during work, which prevents the healthy action of lungs and heart.

II. Where he is exposed to the action of poisonous or irritating substances used in the trade.

III. Where he is called upon to work excessively and irregularly, either mentally or physically.

IV. Where he is compelled to work in confined places in which the air is either initially foul or is likely to become so.

V. Where from the nature of the occupation he is liable to contract harmful habits.

VI. Where he is especially subject to risks to life from accident.

VII. Where he works in atmospheres which contain floating particulate matter. To these may be added another, viz.:—

VIII. Where he is required to work in abnormal atmospheric pressures.

As examples of the first may be cited the occupations of coal and ore-mining, clerk, seamstress, hand-loom weaver, lace-maker (on cushions), glover, shoemaker (on the last), and of bench or machine workers in a sitting or other cramped attitude generally. In all of these, more or less pressure is exercised on the chest, often most marked in the occupation of shoemaking by hand, and in which markedly permanent indentation of the sternum is produced, due to the direct pressure of the last.

Of the second class are workers in arsenic, mercury, zinc and copper, lead, "chrome," phosphorus, chemical workers exposed to fumes of chlorine and sulphur gases, rubber workers to the vapours of carbon bisulphide, and other workers whose atmospheres are composed largely of vapours of tar, pitch, or resin, and others.

Of the third class dock labourers, porters, stevedores, navvies, engineers, and athletes generally may be taken as representative. It has been clearly demonstrated that greater harm results from severe and inconsecutive than from steady, continuous, though severe work. Where the muscular strain is confined solely to certain groups of muscles, as in shorthand writers, pressmen and journalists, musicians, telegraphists, and others, special ill-effects, as writer's cramp, are apt to follow. From the mental side ill-effects are likely to arise where in pressmen and journalists "copy" has to be produced against time, or under exciting conditions.

Tailors, hatters, slop-workers, seamstresses, bookbinders, printers, laundresses, and shopkeepers as grocers and drapers may be considered

as typical of the fourth class, inasmuch as they work usually in confined and often foul air spaces.

Of the fifth class, in which vicious habits are liable to be contracted from materials used or products manufactured in the occupation, the callings of innkeeper, brewer and distiller, barman and barmaid, and of liquor dealers generally, carry with them the temptation to contract the alcoholic habit; that of cigar, cigarette, and tobacco manufacturer, the abuse of tobacco; and that of druggist, the use of opium, cocaine, ether, or other drugs, which when the habit is contracted becomes prejudicial to health.

To the sixth class more or less belong all occupations. But certain of them are necessarily attended by greater danger from accident than others, such as mining or quarrying from the use of explosives, the effects of explosion of gases and of falls of material in railway working, ship-building, house-construction, in connection with machinery generally, and in the manufacture of fireworks and the higher explosives.

The seventh class embraces a large number of occupations, and the factor common to them all which is provocative of harm is particulate matter in suspension in the working atmosphere, and which when inhaled into the respiratory passages produces lung diseases, or when deposited upon the skin causes diseases of the skin. The effects which are produced depend upon the nature of the particulate matter; in respect whether it is organic or inorganic, living or dead, and as to whether its action is purely mechanical or is pathogenic. Where the action is purely mechanical, the character of the air-particles determines in great measure the intensity of the resulting harm both as to time and amount. The dust particles found in this class of occupations may be divided into those that are: (*a*) sharp and angular, (*b*) blunt and smooth, and (*c*) filamentous. In the following trades sharp particles are present, viz., steel grinder (dry process), stone-cutter, sand- or glass-paper maker, potter, button-maker, file-maker (by hand), ore miner, quarrier, and gannister-worker; in the following, blunt and smooth particles, viz., wood or ivory turner, sawyer, collier, miller, baker, foundry-worker, chimney-sweep, and many others; and filamentous, in those of hemp dressing, flax working, hair- and wool-sorting, warehouseman, draper, cotton-spinner, wool-carder, and others. It may be held as expressive of a general principle that the sharper the particles present in the atmosphere and inhaled by the workman, the more rapid the progress and the more severe the character of the lung disease induced. In steel-grinding by the dry process the mortality of employees is exceedingly high, and the rapidity of the disease finds expression in the popular name by which the results are designated, viz., grinders' rot. Of non-metallic particulate bodies, probably the next most disastrous in its effects is that from the working of gannister stone, which is a very compact, highly silicious rock found in various parts of England, and which is used for making bricks which withstand very high temperatures. The hardness of the rock is such that it must be mainly removed by dynamite. All those employed in the industry and especially the grinders are subject to lung-disease, from which the mortality is high

because of the lethal action of its sharp particles. For each 1000 men employed the death-rate of miners is at the rate of 42·3; of grinders, 179·8; and of brick-makers, 22·2 per 1000. These figures alone illustrate by comparison that a dust-laden atmosphere is the most dangerous even in employment of the same material for different purposes. The reader will obtain valuable information on this subject under the following reference.[1] The evil results of substances deposited upon the skin are occasionally seen in persons engaged in the soot traffic as chimney-sweep's cancer, in paraffin workers as skin diseases, and they are commonly found in chrome workers as ulcerative and perforative disorders of the nasal septum, and as "chrome holes" in the form of deep ulcers of hands and arms or other part of body. It is necessary, however, to differentiate between the mechanical action of such particles and the pathogenic action which may arise from some of them. The latter influence may very well be illustrated in the occupations of hair-, wool-, and hide-sorting, and others with relation to anthrax, and rag-sorting and paper-making with relation to small-pox. While according to Bollinger,[2] disease originating from wool treated at the tapestry works of Montpellier was known as far back as 1769, the credit of calling attention in this country to the serious risks of wool-sorting must be accorded to Dr. Bell of Bradford, who with considerable acumen associated outbreaks of disease with certain classes of foreign wool, notably those from Russian Tartary. The Report of the Medical Officer of the Local Government Board for 1880 gives an excellent review of the whole subject, and the Report of the Chief Inspector of Factories for the same year an account of the prophylactic measures proposed to be established against the disease for the protection of workmen. These measures are generally that all suspicious or filthy bales of wool or hair should be steeped and thoroughly soaked in cold water, should thereafter be placed in hot soapy water and be washed, should then be passed through rollers to express the excess of water, and that they should then be sorted. Such procedure prevents the formation and spread of dust in which the spores of *B. anthracis* might be present. Further, the working-places are to be well ventilated, the floors swept daily, the walls and ceiling once in three months, and once a year the walls are to be lime-washed with lime containing carbolic acid. Provisions are to be made whereby the sorters may wash before meals, and it is enjoined that no workman should take into or eat in any sorting-room any food. In the outbreak which occurred in a hair factory near Glasgow, and of which an account was written by Dr. Russell, then Medical Officer of Health for the city, in the Report of the Medical Officer of the Local Government Board (England) for 1878–79 (Eighth Report), several deaths resulted. *Vide* also (Scott), *B. M. J.*, vol. ii. 1900, p. 136. In hair manufactories to prevent the diffusion of dust short hair is treated in an enclosed machine, which is connected with a ventilating shaft by which particulate matter is carried away from the working places. Rag-sorting and paper-making are attended also with risk from floating micro-organisms given off into the

[1] *Journ. San. Inst.*, vol. xxi. Part i. p. 66.
[2] Ziemssen's "Encyc. of Med."

atmosphere from filthy fabrics. Outbreaks of small-pox have been caused on several occasions in this way; one in a paper work in the neighbourhood of Edinburgh, another in the neighbourhood of Glasgow, and a third in central Lanarkshire in 1889. Other outbreaks from different organisms have also been recorded from these occupations. Such an outbreak occurred at Riga in a paper manufactory,[1] from which fatal results arose in some of those attacked. In the blood and tissues of those who died were found micro-organisms, both bacilli and cocci, the former corresponding to Koch's bacillus of malignant œdema.

To the eighth class belongs a very limited number of occupations, as bridge-pier building (in caissons), diving, workers generally under abnormally high atmospheric pressure, and ballooning and mountain-climbing in high altitudes, from atmospheric rarefaction—if such can be classified under the heading of occupation. Where the occupation is carried on under increased atmospheric pressure, arrangements must be made at the entrance to the working parts whereby the air-pressure may be gradually raised to the pressure of the working parts before the workmen are allowed to enter, and may again be gradually reduced before the workmen are permitted to return to the normal atmospheric pressure. The mode by which this is attained is a metal, air-tight chamber, or air-lock as it is called, provided with suitable valves whereby the pressure is raised or lowered. The pressure in the working parts may vary from one half to three or four atmospheres of pressure above normal, the amount of pressure used in any of the above operations being determined by the depth of the working and the kind of material which is to be kept out of the working parts. Various ill effects and even death itself arise from these occupations. The chief effects are the following, viz.: oozing of blood from mouth or nose, rupture of tympanum or tympani, muscular pains and swellings of limbs and joints, vomiting, headache, giddiness, and paralysis of lower limbs, sensory and motor, which manifest themselves on decompression. For further information the reader is referred to Snell's work on "Compressed Air Illness," which besides giving a full account of his experiences during the construction of the Blackwall Tunnel, London, includes the bibliography of the subject.

Statistics of Occupation.—The following Table shows a classification of the population of Scotland, based upon classes of occupation, as taken from the census of 1891:—

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[1] *British Med. Jour.*, 1887, p. 343.

TABLE XXIV.

Classes of Occupations.	Numbers in each Class. 1891.	Percentage in each Class to Total Population. 1891.
I. Professional	111,319	2·76
II. Domestic	203,153	5·05
III. Commercial	180,952	4·49
IV. Agricultural and Fishing	249,124	6·19
V. Industrial	1,032,404	25·65
VI. Unoccupied and Non-productive	2,248,695	55·86
Total Population	4,025,647	100·00

Occupational Mortality.—This will be best illustrated by the following Tables:—

TABLE XXV.

Comparative Mortality Figures in Different Occupations of Males from 25 *to* 65 *Years of Age*, 1890–1892.

Standard: All Males=1000.

Occupied Males	953	Operatives in wool and worsted mills, West Riding, Yorkshire	996
Clergy, Priests, Ministers	533	Operatives in linen and cotton mills of Lancashire	1176
Gardeners and Nurserymen	553	Medical Practitioners	966
Farmers and Graziers	563	Law Clerks	1070
Agricultural Labourers	666	Butchers	1096
Schoolmasters and Teachers	604	Glass-blowers, etc.	1190
Grocers	664	Plumbers, Painters, and Glaziers	1120
Fishermen	845	Cutters, scissors, saw, tool, and needle makers	1412
Carpenters and Joiners	783	Carters, Carriers	1284
Booksellers and Stationers	825	Bargemen, Lightermen, and Watermen	1305
Barristers and Solicitors	821	Musicians and Music Masters	1314
Drapers and Warehousemen	883	Hairdressers	1327
Grooms and Private Coachmen	887	Brewerymen	1427
Coal Miners (mean of several districts)	891	Cab and Omnibus Drivers	1482
Plasterers and Whitewashers	896	Chimney Sweeps	1519
Watch and Clock makers	903	Innkeepers, Licensed Victuallers	1521
Tanners and Fellmongers	911	Messengers, Porters, Watchmen	1565
Shoemakers	921	Filemakers	1810
Artists, Sculptors, Engravers, and Architects	921	Earthenware Makers, Potters	1706
Commercial Travellers	928	Cornish Miners	1839
Corn Millers	957	Costermongers, Hawkers, etc.	1879
Bakers and Confectioners	958	General Labourers (London)	2020
Builders, Bricklayers, and Masons	1001	Inn and Hotel Servants	2205
Blacksmiths	973	Unoccupied Males	2215
Tobacconists	1000		
Chemists and Druggists	1015		
Tailors	1051		
Printers	1071		

The above Table is to be interpreted as follows, viz.: Between the ages of 25 and 65, the same number of men which would contribute 1000 deaths among all males, assuming that equal numbers at the various ages between these ages are employed, would only contribute 533 deaths among the clergy, 1051 deaths among tailors, 1706 among pottery workers, 2205 among inn and hotel servants, and only 891 among coal miners.

Table XXVI.

Comparative Mortality of Men, 25 to 65 Years of Age, in Different Occupations (Ogle), 1881–82–83.

Occupation.	Comparative Mortality Figure.	Occupation.	Comparative Mortality Figure.
Clergymen, Priests, Ministers .	100	Clergymen, Priests, Ministers .	100
Lawyers	152	Builders, Masons, Bricklayers .	174
Medical Men	202	Carpenters, Joiners . . .	148
Gardeners	108	Cabinet Makers, Upholsterers .	173
Farmers	114	Plumbers, Painters, Glaziers .	216
Agricultural Labourers . .	126	Blacksmiths	175
Fishermen	143	Engine, Machine, Boiler Makers	155
Commercial Clerks . . .	179	Silk Manufacturers . . .	152
Commercial Travellers . .	171	Wool, Worsted Manufacturers .	186
Innkeepers, Dealers in Liquors	274	Cotton Manufacturers . .	196
Inn and Hotel Service . .	397	Cutlers, Scissors, etc., Makers .	229
Brewers	245	Gunsmiths	186
Butchers	211	File Makers	300
Bakers	172	Paper Makers	129
Corn and Flour Millers . . .	172	Glass Workers	214
Grocers	139	Earthenware Makers, Potters .	314
Drapers	159	Coal Miners	160
Shopkeepers generally . .	158	Cornish Miners	331
Tailors	189	Stone, Slate Quarriers . .	202
Shoemakers	166	Cab and Omnibus Service . .	267
Hatters	192	Railway and Road Labourers .	185
Printers	193	Costermongers, Hawkers, Street	
Bookbinders	210	Sellers	338

This Table is constructed on the principle that the number of deaths contributed by the profession of clergymen from the same number of all males between 25–65 which contributes 1000 deaths is taken as the figure 100 or standard; and the figures for other occupations, as above, are ratios of that *per centum* figure or standard.

TABLE XXVII.

Comparative Mortality from Phthisis and Respiratory Diseases of Men in Various Dust-Inhaling Occupations.

Men from 25 to 65 Years of Age.	Phthisis.	Lung Diseases.	Phthisis and Lung Diseases.
Fishermen (as standard)	55	45	100
Carpenters and Joiners	103	67	170
Bakers	107	94	201
Wool Workers	130	104	234
Cotton Workers	137	137	274
Cutlers, Scissors Makers	187	196	383
File Makers	219	177	396
Masons, Bricklayers	127	102	229
Stone and Slate Quarriers	156	138	294
Pottery and Earthenware Workers . .	239	326	565
Cornish Miners	348	231	579
Coal Miners	64	102	166

In this Table the mortality from phthisis and lung diseases, separately and conjointly, in the occupation of fisherman is taken as a *per centum* figure or standard, by reason of the comparative freedom from these diseases which persons following this calling enjoy, and the mortalities from the succeeding occupations named are compared therewith and form ratios of the standard figure.

The mortality arising from any occupation depends upon the following factors, viz. : (1) the initial fitness of the employee for the occupation pursued; (2) the nature of the occupation; (3) the environment of the employment; and (4) habits of a vicious character which may be contracted by the workman. At the very outset it should be stated that the foregoing Tables have been compiled from the mortality returns, and from the information supplied at death-registration as to the occupation of the deceased, and on the assumption that the occupation named has been followed during the whole life-time of the deceased. It is obvious that some measure of error may creep in at this stage, since it not infrequently happens that the occupation given has not always been that of the deceased. For example, certain occupations as innkeeping, liquor-selling, shop-keeping, and others have attractions for men who have saved money in their original calling, but in which, it may be, their health has broken down; hence the mortality is debited to the last-named occupation, while, more properly, it ought to be debited to the original. The given mortality rate of a given occupation may not therefore be the result solely of the conditions of that occupation, but is likely to be partly due to that, and to the previously depreciated health derived from a former occupation, or defective physique which has existed initially. Another cause which militates against the accuracy of such returns is that many occupations, because of their light and easy character, attract the initially weak, disabled, or deformed. This is true for example of such employments as clerk, tailor, watchmaker, and others in which much physical exertion is not required. Subject

to these considerations, therefore, the mortality rates given in the preceding Tables may be taken as sufficiently accurate to make it possible to compare the relative incidence of the death-toll of occupations.

But short of producing death, certain occupations produce physical deformity or disability. These need not be elaborated since a glance at the following Table will show illustrative examples.

TABLE XXVIII.

Occupations which Cause Physical Deformity or Disability.

Occupation.	Deformity or Disability.	Proximate Cause.
Boiler Makers, Riveters, or Workers amid concussive noises, Caisson-Workers.	Deafness.	Repetitive Concussion of Tympanum of Ear, Rupture of Tympanum.
Shoemakers.	Indentation of Sternum.	Pressure of the Last.
Tailors.	Peculiar Gait in Walking.	Turk-like Attitude of Lower Limbs when at Work.
Clerks, Students, Scholars, and sedentary workers generally.	Lateral Curvature of Spine.	Faulty Posture of Body.
Telegraphists, Stenographers, Instrumentalists.	Muscular Cramp of Fingers or Hand.	Continuous Strained Use of Digit Muscles.
Clergy (Preachers).	Affections of Throat and Voice.	Unnatural Use of Muscles of Larynx.
Miners, Jewellers, Watchmakers, Scientific Instrument Makers, Microscopists, Seamstresses, Engravers.	Affections of Eye and Vision.	Strain on Visual Apparatus.
Cooks, Gardeners, Car and 'Bus Conductors, Shopkeepers, and persons generally who continuously stand at work.	Varicose Veins and Ulcers of Lower Limbs, Varicocele.	Congestion of Veins from Effect of Gravity and Muscular Strain on Limbs.
Soldiers, Athletes, Porters, Dock Labourers, etc.	Hernias; Diseases of Heart and Large Arteries, as Aneurysms.	Strain on Circulatory System; Great Muscular Effort.
Bridge-pier Builders (in caissons), Divers, Workers under compressed air.	Diseases of Circulation and Nervous System.	Abnormal Atmospheric Pressure.

An obligatory duty has been imposed upon the medical practitioner with respect to occupations, which cannot be neglected without a penalty, viz.: the notification to the Secretary of State for Scotland in Scotland, and to the Home Office (Factory Department) in England, of certain forms of industrial poisoning and disease directly incurred by workmen during their occupation. The Factory and Workshop Act, 1895, section 29, enacts that it is compulsory for medical practitioners to notify every case of lead, arsenic, phosphorus,

or mercurial poisoning, and of anthrax, which is contracted in a factory or workshop. The fulfilment of the duty carries with it a fee of 2s. 6d. for each certificate. The institution of the above provision has proved of immense value to the Factory Department of the Home Office, and much valuable information may be obtained from the Annual Reports on this subject.[1]

No chapter on the Diseases of Occupations could be considered complete without some detailed reference to Factory and Workshop legislation. Formerly this was a serious task to undertake, because of the many Acts of Parliament which bore upon the subject. This bewildering wealth of legislative enactments, however, brought about a remedy by the Legislature itself, viz.: the passing of a Consolidating Act—the Factory and Workshop Act, 1901 (1 Edw. VII. cap. 22)—which came into operation on 1st January 1902, and in which practically all previous legislation respecting Factories and Workshops has been welded into a harmonious whole. Medical practitioners who act or who may yet act under its terms as Certifying Surgeons, and Medical Officers of Health who have to deal with the sanitary aspects of the Act, are, therefore, interested in its consideration.

The Act is divided into ten Parts, and each Part into a varying number of Sections.

Part I. deals with the *health* and *safety* of those employed, and with *accidents*; Part II. with *conditions of employment* with respect to hours and holidays, overtime, night work, intermittent employment, powers of the Secretary of State to impose special sanitary requirements under special circumstances as a condition of employment, and fitness of employment of women, young persons, and children; Part III. with the education of children employed in factories; Part IV. with *dangerous* and *unhealthy industries* and the Regulations to be made concerning these; Part V. with *tenement factories*, *Cotton Cloth* and *other humid Factories*, *Bakehouses*, *Laundries*, *Docks*, *Buildings*, and *Railway Sidings*; Part VI. with *Home Work*, with respect to outworkers in certain trades, employment of persons in unwholesome places, making of wearing apparel where there is scarlet fever or small-pox, and to dangerous processes in domestic factories and workshops; Part VII. with work and wages, with respect to wages for piece-work, and inspection of weights and measures upon which rates of wages are based; Part VIII. with administration of the provisions of the Act; under Sections 122, 123, and 124 with special reference to the appointment and duties of Certifying Surgeons and their remuneration; under Section 132, with respect to Reports of Medical Officer of Health on administration of the Act; and Section 133, with notice to be given by the Medical Officer of Health of employment of a woman, young person, or child when he becomes aware that such is being employed in a workshop in which no abstract of this Act is posted up in a public place in the work as required by the Act; Part IX. with *Legal Proceedings*; and Part X. with the *application* and *definitions* of the Act with relation to the different parts of the United Kingdom.

Factories which come under the Act are divided into two sections, viz.: (A) all places in which mechanical power is used in aid of

[1] *Vide B. M. J.*, vol. ii. 1901, p. 401 *et seq.*

manufacturing processes; and (B) all places named in Part I. of the Sixth Schedule of the Act, whether mechanical power is used or not. The list of industries named in this Schedule contains the following, viz.: print works, bleaching and dyeing works, earthenware works, lucifer-match works, percussion-cap works, cartridge works, paper-staining works, fustian-cutting works, blast furnaces, copper mills, iron mills, foundries, metal and india-rubber works, paper mills, glass works, tobacco factories, letterpress-printing works, bookbinding works, flax scutch mills, and electrical stations.

Workshops include (A) such industries as are named in Part II. of the Sixth Schedule, viz.: hat works, rope works, bakehouses, lace warehouses, shipbuilding yards, quarries, pit banks of metalliferous mines, dry-cleaning works, carpet-beating works, and bottle-washing works, unless mechanical power is used in aid, when they become factories; (B) any other premises in which manual labour is exercised for trade or purposes of gain, and to or over which the employer of the workers has right of access or control; and (C) any work-place—called in the Act a *tenement workshop*—in which two or more persons with the permission of or under agreement with the owner or occupier carry on work. Laundries do not come within the foregoing definitions; but by Section 103, so far as sanitation is concerned, they are to be treated as factories if mechanical power is used, and as workshops if such power is not used. Laundries in connection with prisons, reformatory schools, industrial schools, or any other institution subject to inspection under other Acts, and which are worked by the inmates thereof, are exempted from the provisions of this Act. In like manner are laundries which are worked by members of one family and by not more than two persons outside of the family. The term *work-place*, although not defined in this Act, may be reckoned to come under the interpretation of the word in the Public Health (London) Act, 1891, which was given in Bennett *v.* Harding, 1900 (2 Q.B. 397), viz.: any "place where work is done permanently and where people assemble to do work permanently of some kind or other"; such as restaurant kitchens and like places.

Duties of Medical Officer of Health under this Act.—The Medical Officer of Health is charged with the duty of administering the Act in Workshops and Work-places with respect to their sanitary condition. The term "sanitary condition" of a Workshop may be held to include (a) *Cleanliness*, (b) *Conditions of Air-space*, (c) *Ventilation*, and (d) *Drainage of Floors.*

For these purposes, sec. 91 of the Public Health (England) Act, 1875, sec. 16 of the Public Health (Scotland) Act, 1897, and sec. 107 of the Public Health (Ireland) Act, 1878, apply respectively in these divisions of the kingdom. Cleanliness is to be interpreted to mean a place in a cleanly state and free from effluvia; air-space, not less than 250 cubic feet of air-space per person employed, or 400 cubic feet per person during overtime. Where a place is used as a workshop or work-place during working hours and a sleeping-place at night, it is proposed to enact that the minimum air-space shall be 400 cubic feet. Ventilation is to be held to mean the existence or provision of such means for changing the air as to render harmless so far as

practicable any gases, vapours, dust, or other impurities generated in the course of the work that are a nuisance or are injurious to health. Drainage of floors means that where in any process in which women are employed the floor is liable to be wetted, provision must be made for draining off the fluid. This does not apply in the case where men only are employed. Sanitary conveniences must be provided in any district in England where Part III. of the Public Health Amendment Act, 1890, is in force.

Bakehouses are either factories or workshops in terms of the Act, according as mechanical power is or is not used therein. Sanitary regulations for bakehouses are contained in Sections 97, 98, 99, 100, 101, and 102. These are (1) that a water-closet, earth-closet, privy, or ash-pit must not be within or communicate directly with the bakehouse ; (2) that the cistern for the water-supply must be separate and distinct from any cistern supplying a water-closet ; (3) that a drain or pipe conveying fæcal or sewage matter must not have an opening within the bakehouse ; (4) that all the walls, ceilings, tops of rooms, passages, and staircases of a bakehouse (whether plastered or not) must either be painted with oil paint or be varnished with three coats, or be limewashed, or treated with one or other of these methods combined ; if painted or varnished, the whole place must be washed once every six months, and the painting or varnish to be renewed in three coats once every seven years, and if limewashed, the limewashing to be renewed once every six months ; (5) no apartment on the same level as the bakehouse and forming part of the same building may be used as a sleeping-place unless it is separated by a partition which extends from floor to ceiling, and has an external glazed window of at least nine superficial feet in area, of which at least one-half of said window-space is made to open for ventilation. No *underground bakehouse* may be instituted after this Act has come into operation, and after 1st January 1904, any underground bakehouse existing as such at the commencement of the operation of the Act may not be used unless a certificate of suitability in respect of construction, light, ventilation, etc., has been obtained.

An underground bakehouse means one in which the surface of its floor is more than three feet below the level of the footway of the street or of the ground adjoining or nearest the bakehouse apartment. A *retail bakehouse* is any bakehouse, not being a factory, in which the goods manufactured therein are sold by retail in a shop or place occupied with the bakehouse.

For the sanitary condition of factories the Factory Inspector is held responsible, but by section 5, sub-section 2, he may take with him into a factory or workshop a medical officer of health or inspector of nuisances. Home-work—that is, where work is done for a factory or workshop at home—is dealt with in Sections 107–115. Lists of out-workers, giving names and addresses, must be kept by occupiers of factories or workshops. The Act aims at preventing (1) home-work being done in dwellings injurious or dangerous to the health of the workers themselves, and (2) work being done in premises where exists dangerous infectious disease. When infectious disease is discovered to exist in a home so used, the contractors or occupiers of the factory

or workshop may be prohibited from giving out work to any person who lives or works in the infective house.

Duties of Certifying Surgeon under the Act—Section 122.—The appointment of certifying surgeons is made by the Secretary of State for the Home Department. A surgeon who is occupier of a factory or workshop, or who is directly or indirectly interested therein, shall not be certifying surgeon for that factory or workshop. A certifying surgeon shall conform to the regulations and duties of the office as are made and assigned by the Secretary of State. He shall, if so directed by the Secretary of State, make any special inquiry and re-examine any young person or child. He shall in each year, at a prescribed time, make a Report in prescribed form to the Home Office as to the persons inspected during the year, and the results of the inspection. A poor-law medical officer may act as certifying surgeon to a factory or district in which for the time being there is no duly appointed certifying surgeon. The fees to be paid to a certifying surgeon for the examination and granting of certificates of fitness for employment of young persons and children are regulated in Section 124 as follows, viz.: (*a*) the factory occupier may agree with him as to the amount to be paid; or (*b*) where there is no agreement, the fees shall be paid in accordance with the scale set down in Part I. of the Fifth Schedule of the Act, or with any other scale substituted therefor by the Secretary of State. The fees are to be paid when the examination is completed or a certificate is granted, or at any other time directed by an Inspector. The fee to be paid to him for the investigation of an accident in pursuance of the Act shall be a sum not less than three and not more than ten shillings, as prescribed by the Secretary of State, and shall be paid by the Secretary of State. It is enacted in Section 20 that the certifying surgeon, on receipt of notice of an accident in a factory or workshop, shall proceed with the least possible delay and make a full investigation, and shall within twenty-four hours thereafter send a report thereof to the Inspector.

Ages and Conditions of Employment of Employees.—The employment of any woman or girl, within four weeks after she has given birth to a child, is prohibited by Section 61; the employment of any child under twelve years, in Section 62; and Sections 63, 64, and 65 deal with certificates of fitness for employment of young persons under sixteen and of children in factories, and with the regulations to be observed by the certifying surgeon in granting such certificates. Section 66 gives power to the Secretary of State to require by special order certificates of fitness for employment of such young persons, etc., in certain workshops; and Section 67, power to an Inspector to require a certificate of capacity for work of any young person or child where he is of opinion that such young person or child is incapacitated by disease or bodily infirmity for working daily for the time allowed by the Act.

Duties of Medical Practitioner in Notifying Certain Diseases Contracted in a Factory or Workshop.—Section 73 supplants Section xxix. of the former Act regarding notification of certain diseases contracted by a worker in a factory or workshop. The terms of this Section are as follow, viz.:—

1. "*Every medical practitioner attending on or called in to visit a patient whom he believes to be suffering from* lead, phosphorus, arsenical or mercurial poisoning, or anthrax, *contracted in any factory or workshop, shall (unless the notice required by this sub-section has been previously sent) send to the Chief Inspector of Factories at the Home Office, London, a notice stating the name and full postal address of the patient and the disease from which, in the opinion of the medical practitioner, the patient is suffering, and shall be entitled in respect of every notice sent in pursuance of this section to a fee of two shillings and sixpence, to be paid as part of the expenses incurred by the Secretary of State in the execution of this Act.*

2. "*If any medical practitioner, when required by this section to send a notice, fails forthwith to send the same, he shall be liable to a fine not exceeding forty shillings.*

3. "*Written notice of every case of lead, phosphorus, or arsenical or mercurial poisoning, or anthrax, occurring in a factory or workshop, shall forthwith be sent to the inspector and to the certifying surgeon for the district; and the provisions of this Act with respect to accidents shall apply to any such case in like manner as to any such accident as is mentioned in these provisions.*"

In view of the desire of the Legislature that such noxious conditions should be repressed, various provisions are to be found in the Act towards their prevention. It is enacted in Section 74 that in a factory or workshop where grinding, glazing, or polishing on a wheel or any process is carried on by which dust, gas, vapour, or other impurity is generated and inhaled by the workers to an injurious extent, that ventilation by means of a fan or other mechanical means shall be provided, maintained, and used; in Section 75, that in every factory or workshop where lead, arsenic, or any other poisonous substance is used, suitable washing conveniences must be provided for the workers; that no employee shall be permitted to take a meal, or be allowed to remain during meal hours, in any room in which such poisonous substances are used, and suitable provision shall be made elsewhere in the factory for meal-taking. In Section 76, it is further enacted that no young person under sixteen years, or a child, shall be employed (*a*) in the process of silvering mirrors by the mercurial process; and (*b*) in the making of white lead; no female young person or child in the process of making or annealing glass; no girl under sixteen years, (*a*) in making or finishing bricks or tiles, not being ornamental tiles; and (*b*) in the making or finishing of salt; and no child, in (*a*) dry grinding in the metal trade; and (*b*) the dipping of lucifer matches. Provision is made in the following section (Sec. 78) prohibiting the taking of meals by women, young persons, or children in certain parts of factories and workshops, as for example: (*a*) in glass-works, in places where the materials are mixed, or where flint glass is made, or where grinding, cutting, or polishing is carried on; (*b*) in lucifer-match works, in any part except where the wood is cut; and (*c*) in earthenware works, in places known as dipper's house, dipper's drying-room, or china scouring-room. In all cases notice of the above prohibitions must be affixed in every factory or workshop to which they apply.

THE END

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